HYDRO-ELECTRIC SURVEY OF INDIA.

minary Report on the Water Power Resources of India.

Ascertained during the season 1918-1919 by the late

G. T. BARLOW, C.I.E.,

Chief Engineer, Hydro-Electric Surveys, Government of India, assisted by

J. W. MEARES, M.Inst.C.E., M.I.E.E., M.Am.I.E.E.,

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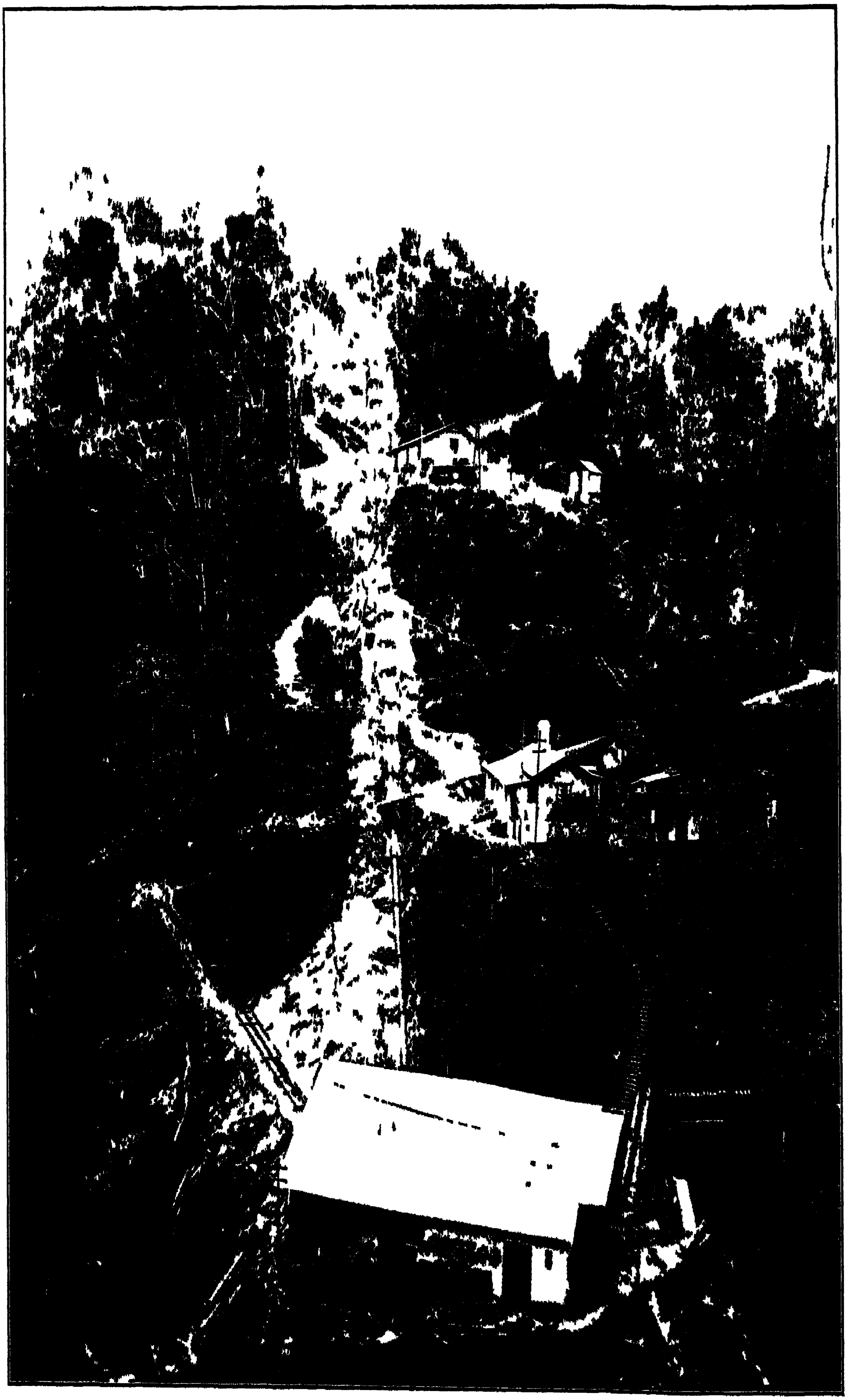

Darjeeling Municipal Electric Works; the first hydro-electric works in India, erected 1897-8.

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INTRODUCTION.

It has always been known that the Indian Empire has great possibilities in the way of natural water power; to a limited extent this power has been developed in a few favourable localities, but as hitherto India has not been to any great extent an industrial country no serious interest has been taken in the subject. Practically the whole of the industries that existed in British India, prior to the advent of the Tata Hydro-electric Power Supply Company, were dependant on fuel. Mysore had however developed considerable power for industrial purposes from the Cauvery River at an earlier date, when the only pre-existing hydro-electric installation in India was the small Municipal town lighting plant at Darjeeling. (Frontispiece) A photograph of this pioneer installation, which was erected and set to work by the present writer in 1897, is reproduced as a frontispiece, as even the Indian Industrial Commission's able Report gives precedence to the Mysore installation which started work in the 20th Century, 5 years after Darjeeling.

In September 1905 the Government of India issued a circular letter to the Chief Secretaries to the Governments of Madras, Bombay, Bengal, Burma, the United Provinces and the Central Provinces (but not to the Punjab) enquiring in general terms as to possible sites where water power might be developed, but the information received was for the most part too vague to be of any great value. Owing to the fact that there was at this time no real demand for industrial power on a large scale, except in cases where promotors were already making their own investigations, the matter was not carried beyond the stage of this preliminary circular.

The outbreak of the war rapidly brought matters to a head all the world over, for it was soon found that power was at the root of all war demands and that electricity was the most adaptable form of power. And whereas Switzerland and the United States, generally associated in the public mind with the chief developments of water power, have utilized only some 24 per cent of their available resources, Germany has utilized no less than 43 per cent

In India, the formation of the Indian Munitions Board was the first step in co-ordinating existing industries for war purposes, and this was soon followed by the appointment of the Indian Industrial Commission. In Chapter VI of the Report of the Industrial Commission, 1916-18, the question of power is discussed in all its bearings, and the necessity for a Hydrographic Survey of India is emphasized in paragraph 99. Reasons are also given (Paragraph 100) why the survey should be undertaken by Government rather than by private enterprise. In paragraph 353 a rough estimate of the cost of the survey is given, assuming it to take 5 years. It is unnecessary to recapitulate the recommendations of the Report in question as the whole industrial future of India, foreshadowed therein, is bound up with and dependant upon the provision of cheap power. The Report itself must be studied.

Acting on the above recommendation the Government of India appointed the late Mr. G. T. Barlow, C.I.E., then Chief Engineer, Irrigation Branch, United Provinces, to take charge of the Hydrographic Survey as Chief Engineer, associating with him in the enquiry Mr J. W. Meares, M.I.C.E., Electrical Adviser to the Government of India. No special instructions were issued to Mr. Barlow, except that he was informed that it was desirable that a preliminary Report should be prepared during the hot weather of 1919; beyond that he was given a free hand and the necessary funds to initiate the work as he thought fit.

The object of this preliminary Report is to explain what has so far been done, and what it is proposed to do in future; and to explain in simple and untechnical language the methods by which every one may assist in the investigation in one way or another. The area to be examined is vast and the work to be done is of great importance; even with the co-operation of the public it cannot be finished for many years, while without that co-operation it will be delayed much longer.

Elsewhere similar work is being carried out either by Government agency or through private enterprise. The Conjoint Board of Scientific Societies in

London formed a Water Power Committee to ascertain " What is at present being done to ascertain the amount and distribution of water power in the British Empire." In July 1918 this Committee (hereafter called the British Water Power Committee) issued its preliminary Report, and this has stimulated an interest in the subject far and wide. The Report states that " With the exception of Canada and New Zealand, Tasmania, New South Wales, and possibly South Africa, practically nothing has been or is being done on any systematic basis to ascertain its true possibilities." A few figures are given relating to the potentialities of India, but these are not always reliable as the Committee had not the information at its disposal for even the roughest approximation, except in one or two places. The British Water Power Committee's Report ends with the following conclusions and recommendations :

Conclusions.

" The main conclusions to be drawn from the evidence available to the Committee are :—

(.) That the potential water-power of the Empire amounts in the aggregate to at least 50 to 70 million horse-power.

(2) That much of this is capable of immediate economic development.

(3) That except in Canada and New Zealand, and to a less extent in New South Wales and Tasmania, no systematic attempt has as yet been made by any Government Department to ascertain the true possibilities of the hydraulic resources of its territories, or to collect the relevant data.

(4) That the development of the Empire's natural resources is inseparably connected with that of its water-powers.

(5) That the development of such enormous possibilities should not be left to chance, but should be carried out under the guidance of some competent authority.

In view of these conclusions the Committee would submit the following recommendations :—

Recommendations.

" 1. That the British Government bring before the notice of the Indian Government, of the various Dominion Governments and of the Governing Bodies of the Crown Colonies, the necessity for a close systematic investigation of all reasonably promising water-powers, and of their economic possibilities.

2. That the British Government take steps to ascertain whether the Governments concerned are prepared to undertake this work.

3. That where such an enquiry is beyond the powers of any governing body, the British or Imperial Government place the work under the direct control of an " Imperial Water Power Board " or " Conservation Commission."

4. That the Government take steps to initiate the formation of such an " Imperial Water Power Board " or " Imperial Conservation Commission," to include a representative from each of the Dominions and Dependencies.

5. That this Board act in an advisory capacity. It should decide on the sequence of such investigation work as comes under its purview. It is suggested that all schemes for the development of which local resources are inadequate, should be submitted to the Board by the Governments concerned, and that the Board should make recommendations on which the Imperial Government might take action.

Such a Board would be able to take a broad and comprehensive view of the advantages to the Empire as a whole, attending the development of any given scheme, and would be able to form a reasonable decision as to the relative advantages of such different schemes as might be brought forward from different parts of the Empire.

6. That since it is unlikely that private capital will be available for many years for hydraulic development on any large scale, powers

should be obtained to enable the State to assist or to undertake such development if thought advisable.

It is suggested that much might be done to attract private capital, if the State, after careful investigation, were to guarantee a suitable minimum interest on the necessary capital, sharing at the same time in any profits beyond the amount necessary to provide that interest. By this method of assistance private enterprise would be untrammelled, and the management of the concerns so assisted would remain in private hands.

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As the Report of this British Water Power Committee may not have been as widely circulated as is desirable the following additional extracts from it may with advantage be given here :

"*The World's Present Power Demand*—It is impossible to estimate with any pretentions to accuracy, the power now being used in the various countries of the world. Independent estimates, based on such data as are available, tend, however, to show that it is of the order of 120 million horse-power made up approximately as follows :—

World's factories, including electric lighting and street railways	.	75 million horse-power.
World's railways	.	21 ,, ,,
World's Shipping	.	24 ,, ,,
Total	.	120

This includes all steam, gas, and water-powers.

"*Cost of Hydraulic Power.*—It must be realised that the cheapness or dearness of energy is purely relative, and hydraulic powers which are not at present able to compete economically with steam, may in the not distant future be able to do so. Even now in favourable localities, the cost of electric power generated from hydraulic installations compares favourably with that of steam or oil power. The cost of such power is made up mainly of charges against capital, interest, depreciation, sinking fund charges, taxes and insurance, which are usually much greater than water charges and costs of operation, maintenance and supplies. These capital charges vary widely with the local circumstances and physical characteristics of the site. Where the available head is great and the storage reservoir is provided by some natural lake, they may be comparatively small. Where, on the other hand, extensive works are required to bring the water to the power house, and where the transmission line is long, the overall cost of power may be largely in excess of that generated by a steam plant.

"An examination of some 120 European installations shows that for large installations of upwards of 10,000 electric horse-power the minimum cost of the hydraulic works is £8·4 per horse-power installed, and the maximum, £79·6 per horse-power. For the majority of the installations the cost lies between £25 and £45. The cost of the electrical generators, switch boards, &c., and transmission lines, also varies greatly, ranging from £1·25 to £28·4 per horse-power, while the cost of the turbines ranges from £4 to £8 per horse-power. The working costs vary between £1·3 and £6·8 per electric horse-power year, with an average value of £3. From these figures it appears that on the average, making an allowance of 15 per cent. for interest and depreciation, the cost per electric horse-power per annum is in the neighbourhood of £10·5.

"In many installations, however, the cost is very much less than this. The Ontario Power Company, for example, is able to supply power to the Hydro-Electric Commission of Ontario at £1·8 per electric horse-power per annum. It is estimated that many of the large powers in Canada can be developed at a total cost, including all generating machinery and transmission lines, ranging from £12

to £20 per electric horse-power in which case the cost per horse-power per annum should not exceed £2 to £3.

"*Necessity for Preliminary Investigations.*—In spite of the great importance of water-power, many of the potential powers in existence must of necessity prove economically useless, either on account of their great distance from centres of industry, the lack of transport facilities, or from the fact that the storage necessary to give a continuous or fairly continuous supply would be too costly. Of many potential powers it can be said without further investigation that for the present this is, and for a long period to come will be, the case. Of others the reverse is true, and it is evident that the scheme will amply repay development. But in the majority of cases the extent to which a scheme is capable of economic development can only be determined after a careful examination of the catchment area and of the site of the proposed works; after a careful and prolonged investigation of the rainfall and run-off records; and, especially in an undeveloped country, after an investigation of the mineral and forestal or agricultural possibilities of the surrounding region.

"It has usually been understood that the usefulness of a water supply depends on the possibility of maintaining its uniformity over the whole period of the year, and that the maximum useful power is strictly limited by the minimum power which, by the aid of any suggested storage system, will be available towards the end of the longest probable period of drought.

"Where the power is utilized for the supply of some industrial centre this is undoubtedly true, but if the idea were to be generally adopted, it would cut out an enormous aggregate of potential power, more particularly in tropical and semi-tropical countries. The possibility of utilizing flood supplies for seasonal operations in connection with mining, agriculture and forestry, or for the production of nitrates in such cases, would appear to be worthy of close consideration.

"In any case, the possibilities of a given scheme can only be determined after a prolonged hydrographical and meteorological investigation of the site and surroundings. To be of real value such an investigation should extend over a long series of years. Rainfall records, though forming the basis of any such investigation, are only of partial assistance in dealing with water-power questions. The actual run-off from the catchment area is the all important factor, and the ratio of run-off to rainfall varies with the physical characteristics of the area, the vegetation, and the climate so that rainfall gaugings cannot be substituted for the more laborious and costly collection of continuous records of river levels, combined with frequent gaugings of flow. It must be emphasized that each scheme of development requires independent investigations to determine completely the local conditions governing the flow from the area intended to be utilized.

"Much can be done to ascertain the approximate possibilities of a potential scheme before deciding to incur the heavy cost of a detailed survey by—

(1) Installation and continuous recording of river gauges on all likely channels.

(2) Installation and recording of rainfall gauges at suitable places.

(3) Observation of river discharges for a series of gauge readings.

"If a reasonably long record of rainfall exists, the determination of the run-off for a few years will serve to give a relation between precipitation and run-off which can be carried back as far as the rainfall records go. The initiation of operations (1)–(3) costs little, and no time is lost in collecting the more important data.

"While this is true, it should be borne in mind—

(1) That to be of reliable value from a commercial point of view the hydrometric studies must give a continuous record for a number of years, and show not only the minimum low water flow, but also

the maximum flood conditions that have to be met in designing the head works.

(2) That the investigation of suitable rivers should include contour plans of the sites, profiles along the entire power reach of the river, and along the banks; also studies of lakes or lochs for storage, where they exist, and of the possibility of inter-connecting two or more such lakes to feed one large project. These studies should be in sufficient detail to allow of preparing preliminary plans and estimating capital and operating costs, in order to demonstrate the capacity available and the commercial feasibility of development.

(3) That to develop the most obvious power site on a river without full investigation of the whole power reach of the river may not secure, and may make it impossible to secure, the maximum advantageous use of the river by the development of two or more sites.

(4) That to secure the maximum possible use of a river the investigations should therefore be made by the Government rather than by private interests.

(5) Especially is this the case where storage may be developed, in order that the maximum possible storage may be secured, and that the water may be equitably distributed to, and the cost of the works equally borne by, the various interests benefited. Proper storage may greatly improve flood conditions and enhance the value of land as well as increase the power available.

(6) That, without complete surveys the capacity of a river cannot be accurately judged. The pondage created by the dam will in many cases more than take care of the daily peak load, thus increasing the power available beyond that due to the minimum low water flow, and this may be still further increased by storage at the head waters. The power capacity of a river may sometimes be increased by such means by 100 or 150 per cent or more."

On his appointment as Chief Engineer of the Hydrographic Survey of India, Mr. Barlow decided to make a preliminary tour over India and Burma, in company with Mr. Meares, in order to get in touch with those who could further his enquiries, to explain the objects in view, and to visit any special localities to which his attention might be drawn, if time could be found for this.

In the period available it was only possible to spend a long time in one Province by omitting others, so it was decided to visit the headquarters of all and to allot what time remained during the season 1918-19 mainly to Burma. As a preliminary step, and in order that engineers in the Public Works Department might know where best to look for possible sites within their divisions, all Chief Engineers were asked to distribute copies of a note on "Practical Conditions in determining the value of Water Power for Electrical Purposes" prepared by the Electrical Adviser to the Government of India. At a later date Mr. Barlow himself prepared a less technical note for the use of officers of other services who might be able to assist in the enquiry, and this has also been circulated extensively. It is reprinted in Appendix I.

The following is a brief diary of the places visited during the cold weather of 1918-19.

1918	November 15 to 17	Delhi	Preliminary meeting of the two officers.
	November 25 to 27	Cawnpore	Mr. Barlow and Mr. Meares.
	November 30 to December 3	Nagpur	Ditto.
	December 4 to 8	Bombay	Ditto.
	December 10 to 14	Madras	Ditto.
	December 16 to 20	Calcutta	Ditto.
	December 21 to 22	Patna	Ditto.
1919	January 2	Delhi	Mr. Barlow only.
	January 4 to 6	Lahore	Ditto.

January 7 to 8	Peshawar	Mr. Barlow only.
January 16 to 17	Shillong	Mr. Barlow and Mr. Meares.
January 18 to 19	Cherrapungi	Ditto.
January 20	Shillong	Ditto.
January 22 to 23	Jatinga river	Ditto.
January 26 to 28	Nagrakata (Jaldaka R)	Ditto.
January 30 to 31	Calcutta	Ditto.
February 4 to 6	Rangoon	Messrs. Barlow, Meares and Raikes.
February 7	Toungoo	Ditto.
February 8	Thandaung	Ditto.
February 9	Toungoo	Ditto.
February 10 to 13	Kalaw and Toungyi	Ditto.
February 14 to 16	Mandalay	Ditto.
February 17 to 18	Maymyo	Ditto.
February 20	Naymyou	Ditto.
February 22	Maymyo	Ditto.
February 24 to 25	Mandalay	Ditto.
February 28 to March 1	Yenangyaung	Ditto.
March 3 to 7	Rangoon	Ditto.
March 28	Jalpaiguri	Mr. Meares only.
March 29 to 31	Darjeeling	Ditto.
April 1 to 2	Jalpaiguri	Ditto.
April 3 to 7	Jaldaka River	Ditto.
March 10	Calcutta	Mr. Barlow only.
March 13 to 20	Meerut	Ditto.
March 21	Bhola	Ditto.
March 26	Aligarh	Ditto.
March 30 to 31	Amritsar	Ditto.
April 2	Lucknow	Ditto.
April 4	Narora	Ditto.
April 9	Narora	Mr. Barlow died.
April 11	Simla	Report begun.

During the visit to Burma Mr. B. Raikes, Deputy Controller of Munitions, and formerly Electrical Engineer to the Government of Burma, was placed on special duty to accompany the Chief Engineer; his knowledge of the country proved most valuable. During this period a certain number of promising sites were examined, though only cursorily; and local officers supplied much useful information and promised to furnish more if their ordinary duties enabled them to spare the time.

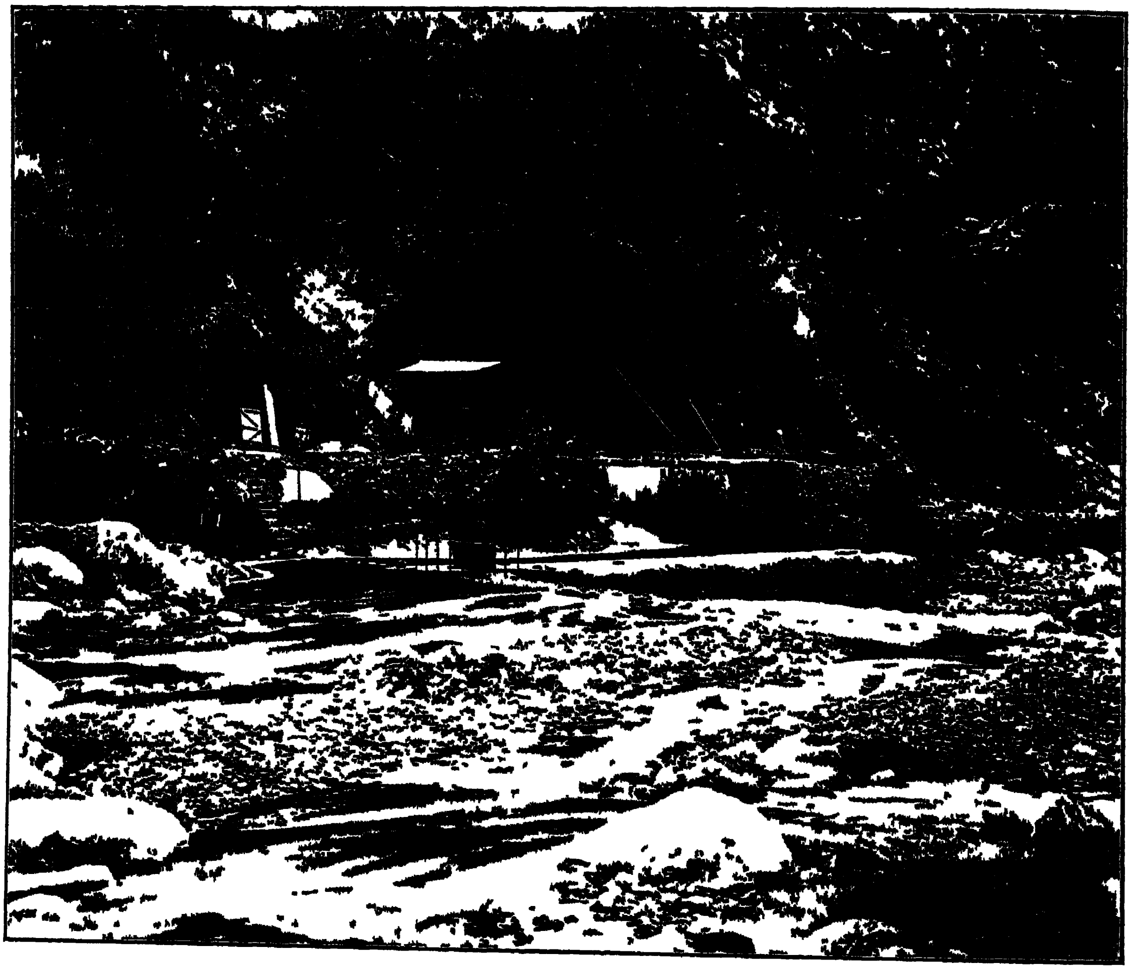
On the conclusion of the month in Burma, the objects of the whole preliminary tour having been accomplished as far as was possible in the time, the Chief Engineer decided that he and Mr. Meares should separate and work independently until April when the report would be prepared; it was his intention that he himself should pay more particular attention to localities where storage reservoirs were likely to be required while Mr. Meares investigated high fall projects.

At this stage of the enquiry Mr. Barlow contracted small-pox and died suddenly at Narora, on the 9th April 1919. His loss to the Government of India is very great, for, despite his extreme care in recording every item of information received, his unrecorded impressions of localities and of men would have proved invaluable when he came to compile his report. Furthermore the late Chief Engineer's special talents, both of engineering and organization, resulting from 33 strenuous years in India, are lost to this important investigation. Pending fresh arrangements Mr. Meares received instructions to carry on the work and to write this preliminary Report.

It will be realized that, owing to the absence of many officers of the Public Works and other Departments on war service, it has been no light

matter for those who remain to give time to the special investigations required on the Survey. In many cases the sites where power is likely to be found are only accessible with difficulty, and their examination may involve several days' journey in country where there are no communications. Gauging operations require technical knowledge and take up considerable time, but unless the *minimum* discharge of a river or stream is known with some approach to accuracy any computations based on it may be very misleading. The discharges of the main rivers already used for irrigation purposes are known, but this is not the case with their tributaries—often likely to be of value—nor with the innumerable mountain streams that have hitherto not been used at all. It is unfortunate that such records have not been kept in the past, as the records of a single year, even if an exceptionally dry year, are a very uncertain guide.

Much valuable work has however been done in these unfavourable circumstances, and in the normal years of the future it is to be hoped that it will be carried to a successful conclusion. It will be observed that owing to vague statements a good number of possible sites for power have not yet been identified. A site should be located either by the exact map square in which it is placed, in the 1 inch to the mile series, or by latitude and longitude. Negative results are in many cases entered in this Report, as they will save useless investigations in the future.



Simla Hydro Electric Works ; The Head Works.

Simla Hydro Electric Works ; Power House and Pipe Line.

PRELIMINARY REPORT.

Note.—In this Report, unless the context shows that a more restricted meaning is intended, "India" is used in its geographical sense as meaning the whole of India and Burma together with the Native States and adjoining territories whose waters find their way into British territory. Similarly the terms Bengal, Madras etc., include the neighbouring States whose waters enter the Province, and it is not intended to mean that the Province in question necessarily has the right of development.

CHAPTER I.—WATER POWER IN GENERAL.

1. *The basis of water power.*—Wherever there is a great natural water fall, such as Niagara or the Cauvery Falls, the public realizes that there is immense power capable of utilization in the service of man; this is the most obvious and spectacular as well as the simplest instance of water power, and most of the early hydro-electric installations utilized such natural falls. In order to make it clear how the power is obtained, and how its amount may be calculated, this typical case of a waterfall will be briefly examined, as it is essential to a proper comprehension of the whole subject matter of this Report.

Pipes are led from a convenient artificial reservoir or "forebay" fed from the river above the fall to a power house at the foot of the same, and the water is passed through these to turbine wheels which generate mechanical power. The turbines may be used to drive any kind of machinery, but in the majority of cases they are used to drive electric generators from which electrical energy is transmitted to wherever it may be wanted. The power is obtained from the *weight of water* falling by gravity through a certain *vertical height*; in the unharnessed waterfall the power is still there, but it is wasted in heat and in breaking up the rocks at the foot of the fall. Controlled by man nine-tenths of the power can be made available on the turbine shaft, and only one-tenth is lost in the conversion. Coming now to the actual computation of the power, or the rate at which the controlled waterfall is doing work, this is expressed in horse-power (h. p.). Unfortunately there are many different varieties of horse-power, and even among engineers they are frequently confused. Thus there is the theoretical (but unobtainable) water horse-power (w. h. p.) in the stream; the mechanical or brake horse-power (b. h. p) given off from the turbine shaft, which is less than the former by the losses in the turbine; and finally the electrical horse-power (e. h. p.) given out by the electric generator which converts mechanical into electrical power, which in its turn is less than the brake horse-power by the losses in the generator. These three are all fundamentally of the *same value*, (*i e.* 550 foot pounds per second) so that it comes to this; that as one gets further from the actual source of power the available amount of h. p. diminishes, owing to the fact that every conversion involves some losses For the purposes of this Report the electrical horse power given out by the generator will be the unit generally employed, with the kilowatt (kW) as an alternative in brackets when necessary, so that the reader need not be troubled with the explanation of electrical units. Neither w. h. p. nor b. h. p. need be further considered. The whole of the data available for this Report are indeed so sketchy that no serious error would result from confusion between the various units. They are however examined in detail in Appendix IV.

With a given flow of water the power is proportional to the fall, *i.e.* 1,000 feet fall will give twice the power of 500 feet, and so on. Again, with a given fall, the power is proportional to the flow, so that 100 cubic feet per second will give twice the power of 50. The fall (or head) is expressed in feet, and may be taken as the difference in level between the point where the water is taken into the pipes (or the head waters where no pipes are used) and the point where it is discharged from the turbine (or the tail waters in a canal or other low fall). The actual net head is slightly less, but this need not be considered at present. The flow of water is ordinarily measured in cubic feet passing a given point per second, often abbreviated to "seconds-feet," but the irrigation term "cusec" is in general use in India and will be used in this Report. The effici-

ency of plant varies greatly according to its size and working conditions of load, but here again it is unnecessary to go into fine detail. An overall efficiency from the water to the electric generator of 80 per cent will be taken as the basis in this Report. Thus the simple formula for the potential electrical horse-power obtainable from any project is:

$$\text{e. h. p.} = \frac{\text{cusecs flow} \times \text{head in feet}}{11}$$

Further technical details will be found in Appendixes I and IV. As an example, the following may be considered;

(*a*) Head or fall 1,000 feet; flow 11 cusecs; power 1,000 e. h. p..
(*b*) Head or fall 100 feet; flow 110 cusecs; power 1,000 ,,
(*c*) Head or fall 10 feet; flow 1,100 cusecs; power 1,000 ,,

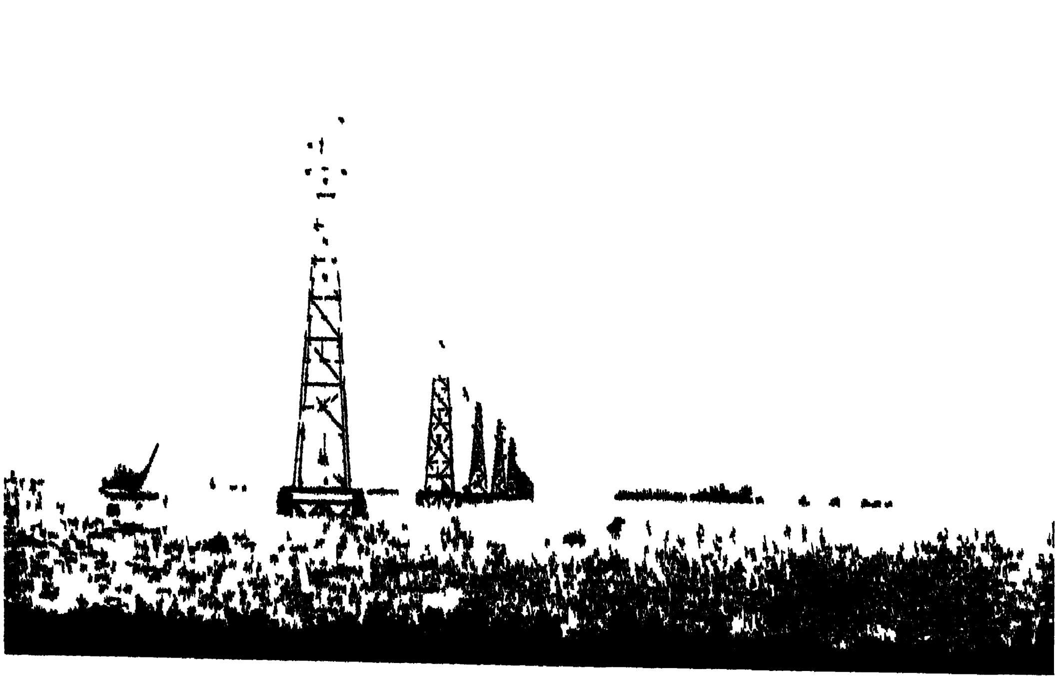
2. *Useless sources of water power.*—Having considered the case of the natural waterfall the other extreme may now be dealt with, namely where there is only a small and fluctuating rise and fall in the water. Correspondence and the records of the Patent Offices show that there is a widespread idea that much power is going to waste in the tides and in the slow moving rivers of the plains; this is true, but in the upshot it is commercial and not engineering considerations that must necessarily prevail, and these are against the utilization of such sources of power. Inventors in modern times have long been anxious to utilize the immense force of the tides, shown by their destructive action on the coast and especially on artificial works designed to control their fury; but here there has been no practical result, *not* because the power is absent but because its utilization would generally be ***prohibitive in cost.*** Again, tidal rivers are a fruitful source of disappointment. It may in favourable conditions be possible to impound the rising water by a dam and thus to obtain the benefit of a fall, both when the tide is rising and again when it is falling; but apart from the enormous capital cost that would generally be involved for a comparatively small amount of power there is the additional difficulty that there would be no power available when the waters on both sides of the dam were at the same height. Once again, mindful of the old undershot water wheels that helped the windmills to grind the people's flour, the possibilities of the great slow flowing rivers often appeal to the fancy as sources of power; but here once more, though considerable power may be going to waste, considerations of cost generally prevent any practical use of the power. It comes then to this, that in the absence of a definite and ever-present fall of at least several feet no water-power scheme is likely to mature as a commercial success. If water were the only source of power the outlook would be different; but it is generally in active competition with other agents such as coal and oil, which are dealt with later in this Report.

3. *Artificial water falls.*—Strangely enough the possibilities that lie between these extreme cases are often overlooked by the layman until attention is drawn to them, for the greater part of the world's water power is now obtained from what may be called artificial water falls. A stroll along the bed of a hill nullah will demonstrate the enormous power of water running down a moderate slope. Boulders the size of a house will be found insecurely perched in the middle of the stream, with the certainty that they have come down from higher ground and will sooner or later continue their course towards the great rivers; indeed the valleys themselves are sufficient evidence of the power of water to do destructive work. It is the hydraulic engineer's business to turn some of this waste to constructive ends, though his utmost efforts will only be as dust in the balance. In order to utilize the power of a mountain stream it is necessary to divert the water from the rapidly sloping natural bed into a gently sloping artificial channel along the hill side; then, after traversing this for a longer or shorter distance, the accumulated fall of the river bed can be concentrated at one point and a fall of many hundred (or even some thousands) of feet obtained; in fact an artificial water fall has been created.

4. *Reservoir projects.*—So far the existence of a running stream has been postulated, but this may generally be supplemented, and sometimes replaced, by storage of water at the top of the fall; whether this is practicable depends

Tata Hydro Electric Works; Lake Sydenham.

Tata Hydro Electric Works; 82-inch pipe near Forebay.



on the configuration of the ground in the first place and on the geological formation when a possible reservoir site has been located. Artificial regulating reservoirs of stone or concrete containing two or three hours' reserve supply against a break in a communicating channel or at the headworks are not here referred to. A further point for consideration in the utilization of natural reservoir sites is the value of the submerged land; this may on the one hand be barren waste or, on the other, highly cultivated land containing villages, the inhabitants of which must be displaced and provided for elsewhere.

The best example of this type of project is that of the Tata Hydro-electric Power Supply Company in the Western Ghats, which is operated entirely from water stored during the few monsoon months; this is regulated to give the necessary flow to the turbines through a fall of some 1,750 feet. Several other similar projects are under construction or investigation in the same district, but in some localities where reservoir sites of large capacity can be traced on the map the rocks are so fissured that a high dam would be useless. The most likely area for projects of this nature, after the Western Ghats, is the Cherrapunji plateau in the Khasia Hills, where the rainfall over a small patch of ground at an elevation of more than 1,500 feet above the contiguous plains is enormous; surveys have not yet been undertaken, but a superficial examination of the ground with an Abney level proved disappointing. Reservoirs of large size would require high dams, and this particular area is subject to severe earthquakes, rendering the "gravity" type of dam dangerous. The future of reinforced concrete has however to be reckoned with, and this form of construction may come to the rescue. A further difficulty here will be that of getting rid of the enormous surplus water during heavy falls, which occasionally amount to as much as 35 inches in a single day, or nearly 2 million tons per square mile of catchment area. Unless there are feasible sites for flank escapes of sufficient capacity it may be impossible to utilize this plateau, even if the dams can be built.

As 100 million cubic feet of water stored will in practice only give some 3 cusecs throughout the year, or 6 cusecs for the dry half year, it will be realized that storage must be on a vast scale where large power is to be developed from it alone, even when working on a very high head. On a low head this type of project is impracticable.

Nevertheless storage on a moderate or even on a small scale may be invaluable as an adjunct to a perennial stream. For whereas power is for the most part only required for some 10 or 12 hours a day, and the requirements fluctuate during this working day, the stream will flow on; so if the unutilized flow during the 12 or more idle hours can be stored it will allow at least double the draw-off during the working hours, and will therefore double the amount of power.

5. *Combined irrigation and power projects.*—India contains a vast system of irrigation works in the form of canals fed both by perennial rivers and from storage lakes. Hitherto the combination of irrigation and power has not made any great strides, although a few canal falls have been utilized and the harnessing of the Periyar Lake has been discussed for a generation. The main disadvantage of such power is its discontinuity; in the first place canals fed by tanks or lakes with a limited supply can only be run when the water is needed for the crops, and, secondly, canals fed by silt bearing rivers have to be closed periodically for repairs and cleaning out. To prevent breaches canals must be closed when rain, sufficient to take care of the crops, falls. Very few, if any, of the Northern India canals have escapes capable of disposing of the supply once the demand slackens, and very few could be provided with escapes at any reasonable cost, if at all. So long as the power is being used to pump water up to irrigate areas uncommanded by the canals themselves, or to drain water-logged land by means of tube wells, stoppages do not matter; for they occur when these operations would be in abeyance. Where however power is to be used for ordinary industrial purposes it may be a serious matter if both the capital and labour employed are kept idle for weeks. Reserve steam or oil plant may then be necessary, and this involves large additional capital cost.

In any part of India where further irrigation works are needed there may be an opening for the combination of these with power supply. Where large reservoirs are involved this is evident, for the tail waters from the turbines may be discharged directly into canals. It is probable that, in order to get suitable ground for such a canal, it may be necessary to sacrifice some "head" on the power plant; but that can well be faced, as such a combined project might pay where it would not do so if confined to either irrigation or power. The cost of the storage works would be met by both undertakings. In the case of the canals fed by perennial rivers the same combination offers attractions. Hitherto, as pointed out at the Punjab Engineering Congress in 1919, the possibility of utilizing canal falls for power purposes has not been taken definitely into account in their design and layout; thus there will often be several small falls in a few miles of canal where a single fall would have been practicable and would have been far better for power development. It is to be hoped that in future this will be borne in mind. Several small falls are however preferred for irrigation purposes on the score both of economy in construction and of facility of command.

6. *Descriptive Classification of water power.*—Having cleared the ground by explaining the "general idea" of water power the various types met with may now be further classified. In the first place a scheme may be developed on

(*i*) a high head
(*ii*) a medium head
(*iii*) a low head.

There is no exact line of demarcation between these, except according to the type of turbine wheel generally adopted. Thus high heads are those in which the Pelton type of jet impulse turbine is used, generally from 300 or 400 feet up to the limit of nearly 5,000 feet; the flow of water required for a given plant is here the minimum. Low heads are those in which pressure or reaction turbines are used, either completely submerged or with draft tubes, extending from the lowest practicable limit of about 3 feet up to about 80 feet and requiring a very large volume of water. Medium heads lie between these extremes and employ a variety of types of turbines, mostly impulse, but generally not of the Pelton type except in America.

The second basis of classification is according to whether the water supply is perennial, or from reservoirs, or a combination of the two.

Yet again, there are various methods by which the head or fall is obtained, *viz.*:—

(*a*) A natural waterfall with merely a pipe line conveying the waters from above the fall down to the turbines in the power house below it, as described in the first paragraph. This may be a high, medium or low fall, fed by a perennial stream, or storage, or both.

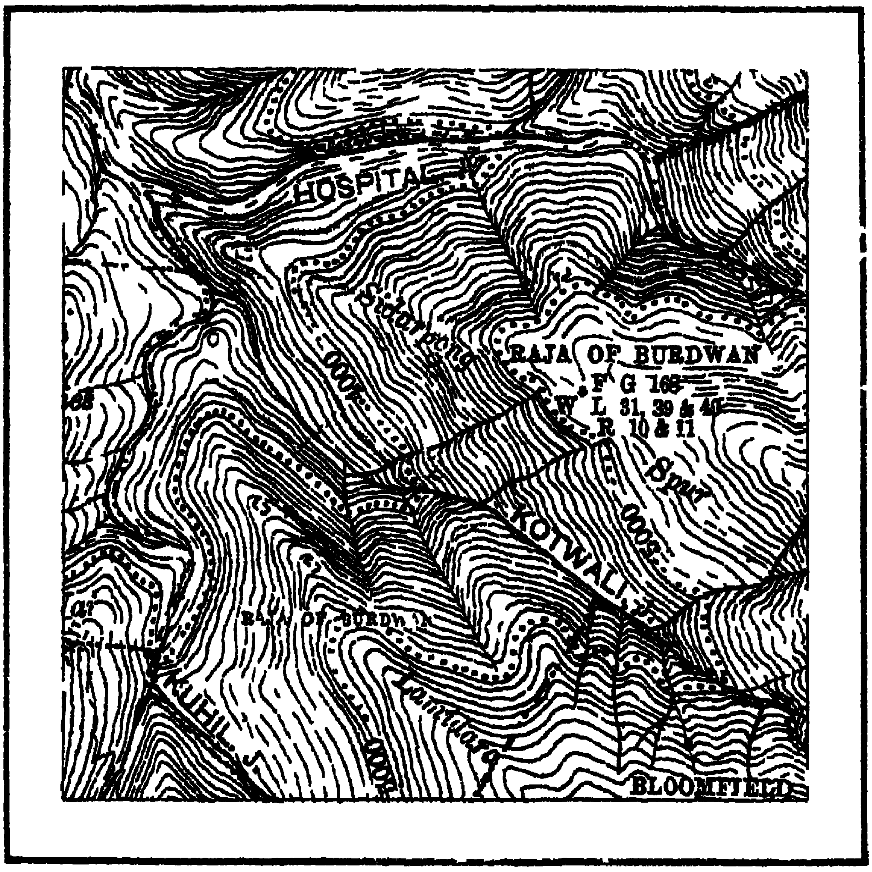
(*b*) An artificial fall created by a dam *alone*, the water being taken from the upper level to the lower level through the turbines. Sometimes the power station itself will be contained in the interior of a hollow dam. Such an arrangement may be utilized for either a medium or a low fall. A succession of rapids in a river is often dealt with in this manner, and a canal fall is a special instance of it also. The water stored behind the dam will generally remain at the highest level, constantly fed by the stream or canal, and if it is drawn upon the fall available will soon diminish or even disappear. If however the waterspread of the reservoir is great it will generally be permissible to use it for regulating purposes, as a few feet of depth may be sufficient when utilized to allow the whole incoming flow of the day to be used during the ordinary factory hours.

(*c*) An artificial fall, developed by tapping a perennial stream or a reservoir at a high level and conveying the water in an artificial channel to a point where pipes can be taken down to a power house at a lower level. Very high heads are invariably so obtained, and the method is also applicable to medium heads and even to very low heads, such as combinations of two or more canal falls. The supply

DARJEELING

LAYOUT OF HYDRO-ELECTRIC WORKS

Scale 2 Inches = 1 Mile



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REFERENCES

Original channels
" reservoir
" pipe line
" power house
Extension channel
" reservoir
" pipe line
" power house

may be either perennial, or from storage, or from a combination of the two. There is great variety in this class of project. Ordinarily the artificial channel, which may vary from a ditch to a large canal or from a galvanized iron or concrete culvert to a huge wooden flume, is taken along the contours of the hill side on a very gentle slope of from 1 in 500 to 1 in 2,000. Sometimes the stream will make a great hair-pin bend, and a tunnel through the intervening spur will save miles of open channel and many feet of useful head, while avoiding ground on which landslips may occur and cause interruptions to the supply. Again, there may be abundance of water in a high valley sloping very gently away to the plains while on the opposite side of the watershed there is a steep fall offering a far cheaper development of the pipe line and a better site for the power station; here the water may be taken through the watershed in a tunnel and then piped down to a power house in another catchment; or again, several different streams may be tapped and channels from each of them led to a single point where there is a good fall. A perennial flow is almost invariably a feature of such schemes, but this may be supplemented by storage; and this storage either may be of comparatively small amount at the top of the pipe line, for regulating purposes, or may be at the source of one of the channels or in the upper reaches of the stream, for augmenting the supply over long periods.

Instances may be found of all these types and of many minor variations of them, and in any given case it is not difficult to decide which method of development will prove feasible. In dealing with any project that may be classed as "low head" special difficulties are met with owing to the great seasonal variation in the water level; the monsoon rains, or even a local storm may cause a great rise in the level and it not infrequently happens that the rise is greater below the power house than above it, so that the available fall is diminished. In narrow channels this is particularly likely to occur, so a gorge is generally a bad location.

The illustrations and layout maps in this Report illustrate varieties of type (c) above, as will be seen from the data relating to the Darjeeling, Simla and Tata works in Table 1, para. 23. Thus, at Darjeeling (Frontispiece and Map 1) three separate hill streams are brought by small contour flumes to a masonry regulating tank which feeds the pressure pipes of the turbines; this tank is also fed by the tail waters of a subsidiary power station above it which taps one of the same streams at a higher point. In the case of Simla (Plate 2 and Map 2) a single stream is led by a concrete flume to the masonry regulating reservoir; thence a closed concrete pipe leads to the forebay from which the pressure pipes take off. In both these instances perennial flow is depended on, as the storage is only sufficient for a few hours; and settling tanks are provided to deal with the large amount of silt and débris brought along the channels. The Tata works (Plate 3 and Map 3) depend entirely on storage from three lakes, which, by means of canals and a tunnel through the watershed, feed the forebay from which the pressure pipes run down to the power house.

CHAPTER II.—WEATHER AND WATER.

7. *Incidence of rainfall.*—In certain important respects India differs from most countries whose natural resources in water power are now being investigated; for the rainfall is seasonal, and during many months only occasional thunderstorms break the monotony of dry weather. Generally speaking there is the monsoon period and the dry period, but in the South there are two distinct monsoons, the South-West and the North-East. The variations in the rainfall in different parts of the country are enormous, and the departures from the monthly and annual normals in any given locality are also very great. Apart from canals, it is to the mountainous regions that we must look for water power, and here the rainfall is naturally greatest; especially in those hills that first catch the moisture laden winds from the sea. The great central plains of India mostly have low rainfall, but here comparatively little power would in any case be found owing to the extremely small slope of the ground and the great variations in the normal water levels.

The arid area in the North-West covers mountainous districts, mostly trans-frontier, and even if power were available it is doubtful if much use could be made of it in such unsettled country. This last consideration applies also to various mountain ranges in the Northern Burma region, which are either "Unadministered Areas" or are inhabited by uncivilized tribes; but in some of these areas there is good rainfall.

Except in localities where storage on a very large scale is possible, such as the Western Ghats and possibly the uplands of the Central Provinces, the greater part of the *monsoon* rainfall of India must necessarily pass to the great rivers and canals undeveloped for power purposes. Thus for example, take the case of the Jaldaka River in the Bengal Duars, a stream with considerable possibilities; it has a catchment area in the neighbourhood of 250 square miles above the point where it enters the plains, and the annual rainfall is not less than 150 inches; probably it may average 200 inches. This nearly all falls in the 7 months of April to October and amounts to some 75,000 million cubic feet, giving an average flow of nearly 4,000 cusecs and a maximum flow enormously greater. Yet the flow gauged in April 1919 was no more than 170 cusecs. Clearly in the absence of a phenomenal reservoir site—and the Himalayas appear to afford few such—most of this water must run to waste. Furthermore the control of such a river, when a single day may bring 10 inches of rain or more, is no light problem; and this is one of the smaller rivers in the district. It serves however as a good example of many potential sources of power.

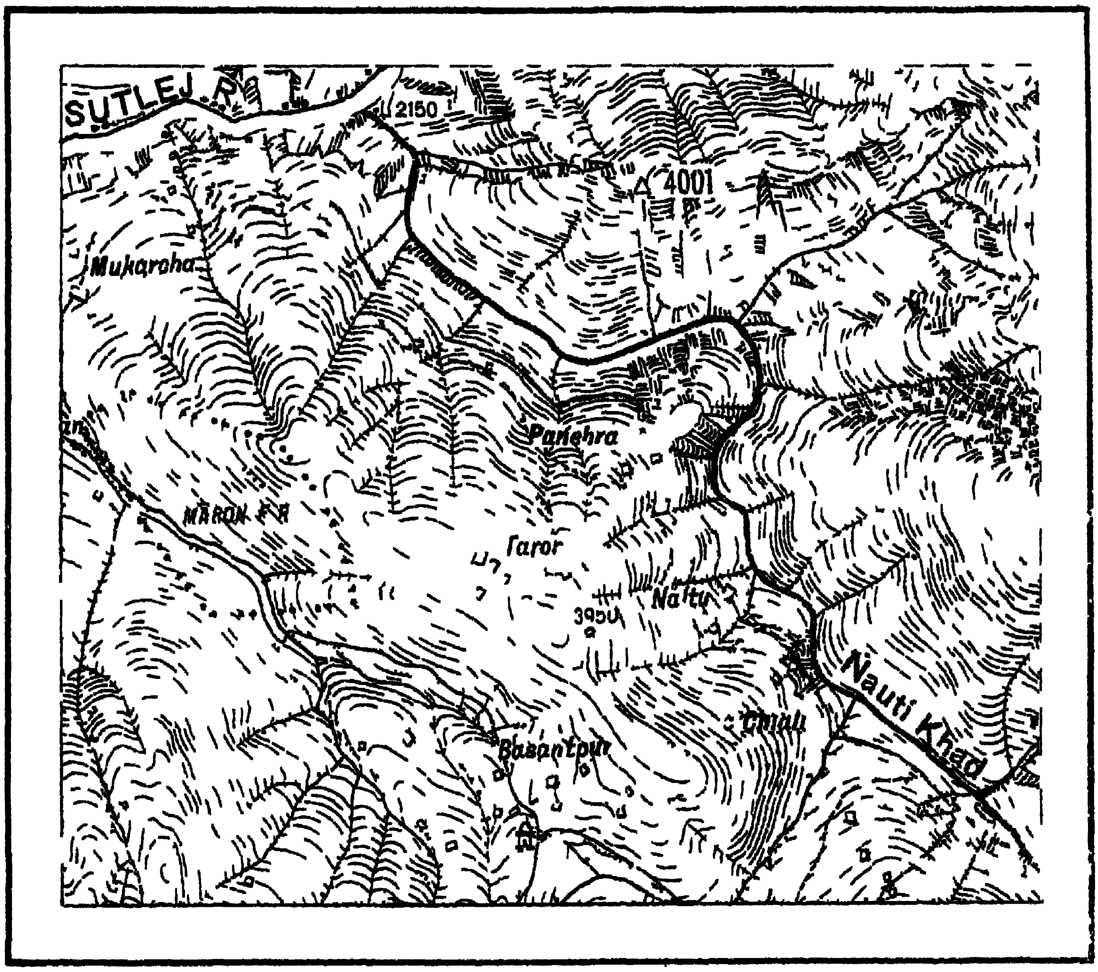
The Bhakra dam project on the Sutlej, now under detailed investigation, has drawn attention to many other sites that may prove suitable for storage both on the Sutlej and Ravi rivers, and similar sites may be found on other northern rivers.

8. *Perennial and seasonal rivers.*—As the result of the conditions discussed in the preceding paragraph many of the rivers and streams of India fall to a very low ebb, or dry up altogether in their higher reaches, before the end of the dry season. Where this is so development by monsoon storage is the only method of getting continuous power, and this is not possible in most localities. It is true that discontinuous water power may be of value in particular instances, either for utilization in industries that are only manufacturing during the rainy season, such as tea, for which the power demand for drying and other processes is very large; or for any purpose in combination with reserve plant driven by steam or other fuel. In either of these instances however the cost of the power will be higher than it would be if continuous, as the capital charges on the plant are higher in the second case and spread over a shorter working period in the first.

SIMLA

LAYOUT OF HYDRO-ELECTRIC WORKS

Scale 2 Inches = 1 Mile



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REFERENCES

Headworks

Channel with tunnel and silt tanks

Reservoir

Concrete pipe

Forebay

Pipe line

Power house

The perpetual snows of the Himalayas are responsible for the hot weather flow in most of the perennial rivers of Northern India, and may prove an asset of immense value for industrial power just as they already are for irrigation. Even the comparatively low lying snows will last on well into the hot weather, feeding the springs and keeping up the volume of water. There is however very little of this "White Coal" (*houille blanche*) in other parts of India, and such perennial streams as exist are spring fed. Burma is especially well off in this respect, but often the springs which appear at one point will disappear in a similar cleavage a little further on, so that there is only a slender chance of being able to supplement the flow with storage in ground so badly fissured. The disadvantage attaching to the Himalayan snows is that they lie almost exclusively in trans-frontier regions, and exhaust most of their fall to the plains in Kashmir, Tibet, Nepal, Sikkim and Bhutan. The boundary lies for the most part near the foot-hills, and while the water can be used thereafter for irrigation it has reached the inert stage (paragraph 2) from the power point of view.

9. *Rainfall and run-off.*—Into the highly technical subject of rainfall and run-off it is only necessary to dip for a moment. Clearly all the rain that falls in a given catchment area will not at once (if ever) find its way to the stream in the valley; some will evaporate altogether, or sink into the ground to feed springs in other catchments, or be absorbed by vegetation, and the more gradually the rain is precipitated the greater will be these losses. Very light rain after a dry spell may not affect the flow of the stream in the slightest degree. Again, if the ground is steep, barren and rocky there will be a much more complete flow from it than if it is gently sloping and covered with vegetation. The percentage of the rainfall that reaches the stream is called the run-off.

If the rainfall over a particular catchment area in any period is known, and the stream flowing from it can be gauged, the percentage of run-off can at once be calculated for the conditions obtaining during that period; but the rain-gauge readings must be taken at a number of points in the catchment —the more the better—in order to ascertain the actual amount of precipitation. In addition to the very large differences of average rainfall in different countries and localities, and the great variations from the average in particular years, the distribution of the fall month by month and day by day must be taken into account. Minimum discharges on small catchments may vary 4 or 5 fold in different years, and are extremely difficult to calculate; a long series of rainfall averages will however, indicate to some extent the relation between the unknown discharge of an exceptionally dry year and the known discharge of a particular year. Intelligent guesswork of this nature presupposes knowledge of local conditions and long experience.

Formulæ for calculating the maximum run-off from a catchment have been devised by many Engineers, but they all employ coefficients which it is impossible to ascertain without a comprehensive study of the nature of the area and the rainfall.* It may however be accepted that a study of the daily rainfall observations over a period of 30 years will give a fairly accurate idea of the conditions which are likely to occur in future, and if different percentages of run-off are assumed for light, medium and heavy falls, depending on the nature of the catchment, a fairly accurate forecast can be made.

As a practical example of the method the following empirical table was tentatively adopted by the late Mr. Barlow, in the United Provinces.

Light falls under ½ inch in 24 hours should be entirely omitted unless continuous for several days ; falls from ½ inch to 1 inch in 24 hours should be omitted if there has been no fall before or after. Falls from 1 inch to 1½ inch, when not followed or preceded by similar or greater amounts, are considered light.

Medium falls are those from 1 inch to 1½ inch when followed or preceded by any but light falls ; also all falls from 1½ inch to 3 inches.

* See chapters on "Rainfall" and "Maximum flow off a catchment" in Buckley's "Irrigation Pocket

Heavy falls are those over 3 inches or continuous falls over 2 inches a day; also all falls of an intensity of 2 inches an hour or over.

Table showing percentage run-off assumed.

	A	B	C	D	E
Light falls	1	3	5	10	15
Medium falls . . .	10	15	20	25	33
Heavy falls	20	33	40	55	70

A=flat cultivated and black cotton soil catchment.
B=flat partly cultivated and stiff soils.
C=average catchment.
D=hills and plains with little cultivation.
E=very hilly, steep and rocky with very little cultivation.

Obviously such a classification would be unsuitable in most parts of Europe or America, but it brings out clearly the nature of the variations to be met with in a particular locality. A thunderstorm with a rainfall of ¾ inch in 20 minutes would give double or treble the run-off of the same fall spread over a day; but nearly all rainfall observations give the daily fall and not the hourly intensity. The classification of daily rainfall over a long period sounds a serious proposition, but is really a matter of clerical labour only. Owing to the disturbing effect of hills, etc. isolated observations at one point of a catchment may be very misleading; hence the necessity of many gauging stations wherever possible. Rainfall contour maps are only useful as a general guide, unless prepared on a large scale from observations made for the purpose.

In India the rainfall varies in different localities from 450 to a few inches, mostly precipitated in about 4 months, while catchment areas vary in nature from waste sand to steep rocky country. In some parts the ground is highly cultivated or covered with dense forest, while in others there is hardly any soil or vegetation; the soil itself varies from the stiffest clay to the lightest loam or sand. With these variables it is easy to realize that the run-off must vary greatly and is incapable of treatment by any general formula of universal applicability.

Evaporation and percolation.—Apart from the fact that a considerable percentage of rainfall is evaporated before it reaches the big rivers, as well as from their surface, the question of evaporation arises wherever long canals or large storage reservoirs are employed. The actual amount of evaporation varies so much that no general figure would be of the slightest value; in India it may be as much as 6 feet in the year, but for details of many known reservoirs Buckley's "Irrigation Pocket Book" may be referred to. Percolation and absorption also account for no small amount of the water entering a canal in natural ground or a reservoir, but the loss must obviously be determined in each case as it arises.

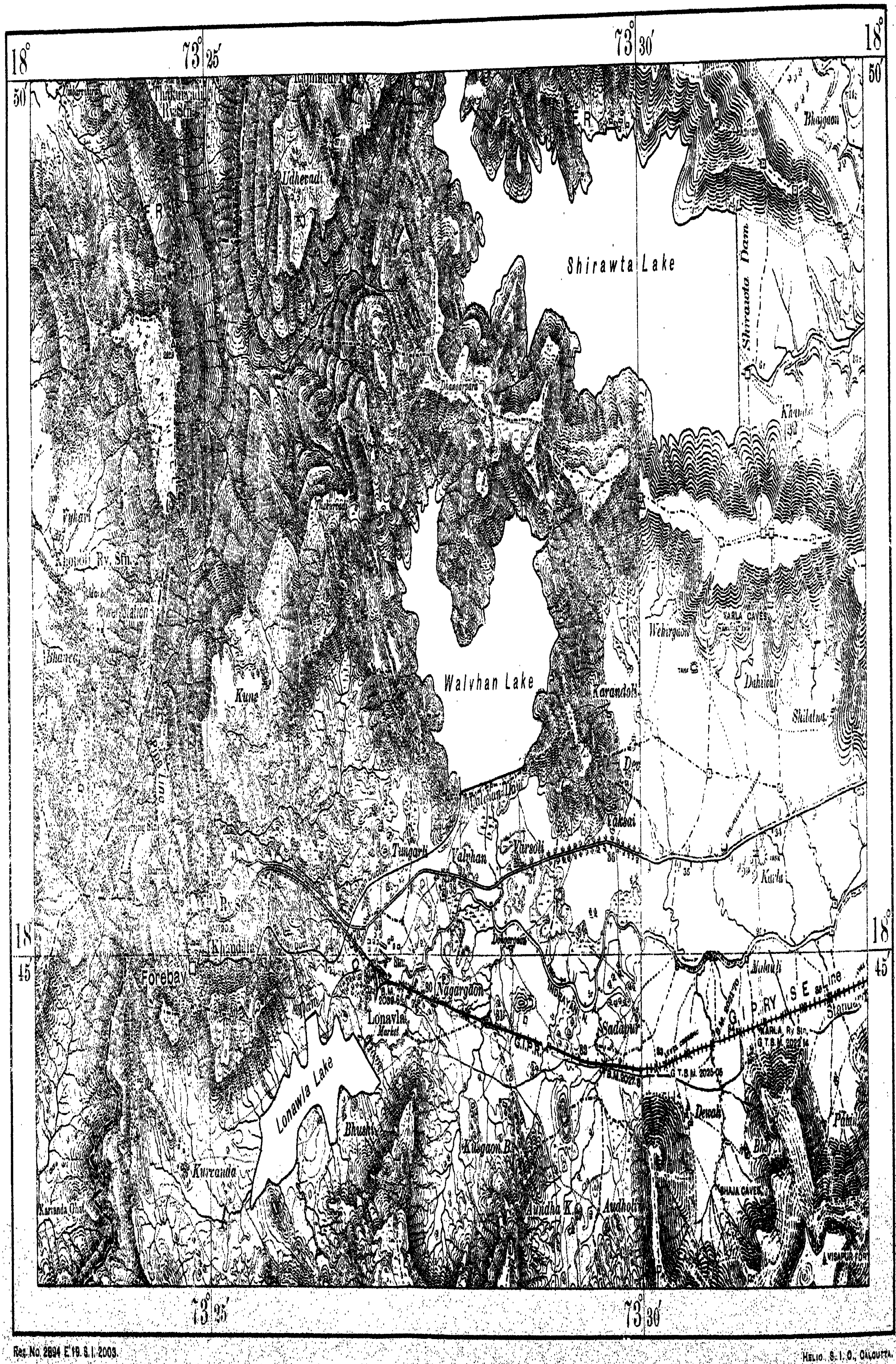
Where rivers are fed from the highest mountains the precipitation is largely in the form of snow, and the immediate run-off is small; the melting of the snow from about April onwards coincides with the driest season, and thus tends both directly to equalize the flow of the rivers and also to feed distant springs. At times however the more sudden melting of the snows brings down heavy floods, whether due to rainfall, as on the north-west frontier, or to hot winds, as in the Himalayas further east. To a certain extent also level marshy ground has an equalizing effect, acting as a sponge; and this property may be very valuable as it can in some cases be reproduced artificially by a series of low embankments and terraces.

10. *The measurement of a discharge.*—Wherever a stream offers possibilities of water power it is necessary to ascertain the minimum flow of water in it; this however may involve waiting for years, as it is only after an exceptionally dry season or succession of dry seasons that the true minimum is reached; and as this was the case in many parts of India in the cold weather of 1918 it may

TATA HYDRO-ELECTRIC WORKS

GENERAL LAYOUT

Scale 1 Inch=1 Mile



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value, as some indication of the true minimum may then be obtained by examination of rainfall records in the neighbourhood, especially if the average run-off is known. To the skilled observer the method of taking a discharge is familiar; the usual constants will be found in Appendix II. Many persons not accustomed to this work—especially Forest officers and followers of Isaac Walton—may, however, be able to render invaluable help by estimating the flow of streams in out-of-the-way places. The amount of water in cubic feet per second (cusecs) flowing past a given point in any open channel is found by multiplying the cross-sectional area of the water in square feet by its *mean* velocity in feet per second.

Where the correct methods and co-efficients to be employed are unknown, the following very approximate method may be adopted:—

Select a straight reach of the stream where the flow is uniform and where there are no noticeable pools, and mark off with pegs any convenient length of fairly uniform width. Then measure as accurately as possible the width of the stream, and find the *average* depth by soundings at intervals across the stream. Then throw into the centre of the stream a small stick and note the time it takes to pass along the marked length; repeat this 4 or 5 times to eliminate errors. Then the run or length in feet divided by the average time in seconds gives the velocity on the surface. Then the cross-sectional area in square feet multiplied by the surface velocity in feet per second and *divided by two* will give the approximate discharge in cubic feet per second.

For instance, suppose the length marked off is 100 feet and the floats take an average time of 50 seconds in passing along this length, in a stream having a width of 40 feet and an average depth of $1\frac{1}{2}$ feet. This gives a cross-sectional area of 60 square feet. The surface velocity will then be 2 feet a second and the discharge $\frac{2 \text{ feet a second} \times 60 \text{ square feet}}{2} = 60$ cusecs.

The reason for dividing by 2 is that the mean velocity throughout the channel is much less than the surface velocity, and the rougher and shallower the bed may be the greater will be the disproportion; in the worst cases it is about half.

It sometimes happens that soundings cannot be taken in unfordable hill streams, and another very rough method which has proved of occasional use may be mentioned. Gaugings were required of a river, partly snow fed, at its junction with a smaller hill stream. The discharge of the latter was satisfactorily determined, but that of the former could not be measured. The temperature of the larger river was found to be 60°; that of the smaller one 61°; and of the combined river some little way down stream 61°. Then the volume of the large stream is thrice that of the smaller, for

$$\begin{array}{lcr} 60 \times 3 & = & 180 \\ 64 \times 1 & = & 64 \\ \hline \end{array}$$

CHAPTER III.—LOCALITIES AND SURVEYS.

11. *Geographical considerations.*—Leaving aside for the present the canal falls and low river falls that it may be possible to develop in the plains a glance at the layered 16-inch Atlas sheets of the Survey of India shows that (without going into details) the following mountainous or hilly regions promise medium and high falls, where there is water enough to use them.

(*i*) The whole of the Himalayan and associated ranges that mark the Northern frontiers of India, from the Quetta District in the west right into the Northern Districts of Burma. Perpetual snows feed the great rivers and many of the smaller ones along the whole reach. (Atlas sheets 34, 35, 38, 39, 43, a corner of 44, 52, 53, 62, a corner of 63, 71, 72, 78, 83, 92). Unfortunately a great proportion of this territory lies outside British India; in Baluchistan and Afghanistan on the west, Kashmir and Jammu in the middle West, Tibet and Nepal in the central districts, Bhutan and Sikkim in the East and finally Yunnam in the extreme East. The Western part of the region is in the dry zone, and for the most part is not likely to offer much power; the remainder has considerable possibilities (*vide* rainfall map). Sheet 78 also contains the Khasia hill group, with high plateaux and great rainfall.

(*ii*) The West coast, comprising the hills from the Aravali Range in Udaipur, the whole of the Western Ghats, the Nilgiri Hills, and on down to Cape Comorin (Atlas sheets 45, 46, 47, 48, 49, and the Western part of 58; sheets 40 and 41 have no high ground and scanty rainfall).

(*iii*) The East coast from the Eastern Ghats and Ganjam down to Cape Comorin. Atlas sheets 57, 58, 65, 66, 73, 74; sheet 79 which includes Calcutta offers nothing except perhaps in the patch of the Chittagong hill tracts at the Eastern corner.

(*iv*) Of the remainder of the peninsula, inland, there is prospect of but little power in the parts of Rajputana, Central India and the United Provinces shown on Atlas sheet 54. The Central Provinces have considerable possibilities in the areas shown in Atlas sheets 55 (comprising the Chhindwara area) and 64, while the Bundelkhand and Baghelkhand hills on sheet 63 also merit further investigation. Hyderabad and the surrounding districts on sheet 56 also have considerable elevation, but the rainfall is precarious and there does not appear to be much indication of steep falls to the lower ground.

(*v*) Practically the whole of Burma, both the coast line and the interior up to the Shan States, offer great possibilities, especially as there are far more perennial rivers and streams here than elsewhere. (Atlas sheets 84, 85, 93, 94, 95, 96, 102).

12. *Maps and existing surveys.*—The Atlas sheets of India, which have been quoted in the preceding paragraph, are for the most part complete in the layered edition though a few are still in the preliminary or provisional stages. For the initial examination of a possible water power site no map on a scale of less than 1 inch to the mile is of much value, and then only if it is contoured. Many sheets on this scale have been issued by the Survey of India, but many still remain to be done; and, of those issued, a large number are not contoured but only show hills by "form lines" or "hill shading." Form lines are of little value in deciding how a channel can be taken from one point to another, or what capacity a dam will give, while these can be determined approximately on even a 1 inch contoured map. Hill shading is valueless for the purpose. It is particularly unfortunate to this investigation that so many of the most likely hills have hitherto not been mapped in detail, though it is quite natural that the more civilized areas should have been done first. For water power will as often as not be found in remote and inaccessible hill ranges, of [illegible]

lines, are available for considerable tracts of country, including much high ground that may contain water power. Where this is so these maps are invaluable, but they are apt to end in a tantalizing manner just at the mid-point of a possible project, and there are many gaps in the middle of mapped areas. In addition to the above there are certain areas mapped on the scale of 2 inches to the mile; and the tracing out of contours on these is much less fatiguing than it is on the one inch maps.

A careful study of the largest contoured maps which are available will be found of great assistance in all reconnaissance work. In dense jungle or rough country it is frequently impossible to follow up the course of a stream, and unless the maps are carefully studied it may easily happen that a useful fall or a promising reservoir site is missed. A few examples are given below to indicate the kind of information which can be obtained from maps:—

(*a*) A flat or a steep valley or hill side is shown by the distance between the contour lines. The closer the lines are the steeper the country will be found.

(*b*) The distance between any two contour lines which cross a stream will give the fall in that reach.

(*c*) Absence of village sites and roads or pathways denotes wild or uncultivated country.

(*d*) Numerous habitations on the hill slopes or in a valley in hilly country denote cultivation, and generally springs or perennial water in the streams.

(*e*) When the discharge of a stream is known at a certain point, an idea of the discharge at another site can generally be guessed by a comparison of the catchment areas at the two places.

(*f*) By a study of the nature of the valleys and the hill sides, a fair idea can be obtained of the general nature of the country, and its possibilities with reference to reservoir sites, slopes of the stream, and places where an artificial fall for power purposes can be found.

(*g*) When a stream makes a long hair-pin bend, it is frequently possible to obtain a good fall by diverting the water in a tunnel across the neck of the bend. Several miles of a river can sometimes in this manner be replaced by a short cut diversion of a few furlongs.

(*h*) Sometimes the slopes on one side of a water-shed are very steep, while on the far side they are gentle, when this happens it may be possible to form a reservoir and divert the water through the hill, and by this means obtain a most useful artificial fall.

(*i*) By tracing a contour line along both banks of a stream, from any point that appears favourable for the head works of a power scheme, some idea can be obtained as to the possibility of carrying an open channel along to where there is a steep fall. Often one bank is much more favourable than the other, owing to the absence of cliffs or large nullahs which would have to be crossed or to very bad rock, as on the Jhelum Valley road, where the clay is found now on one bank and again on the other.

Where no contoured map can be obtained it is impossible to decide whether a development is practicable or not without a special survey, a lengthy and expensive matter. An examination of the ground by a trained observer, who knows what to look for, with an Abney level, a pair of aneroid barometers, and a thermometer, will however generally indicate whether such a survey is likely to be justified or not. This however is not likely to be of much value except in cases where the minimum discharge of the stream is already known—and it rarely is—unless undertaken in the driest period of the year, when gauging of the flow can be combined with examination of the ground and the rough determination of heights.

13. *Aneroid surveying.*—For the guidance of any person who may be able to examine new sites for water power it, may be explained that while a mere record of the difference in height between two stations as given by an aneroid—*i.e.* between a possible head works and a power house site—is of value, the "reduction" of such observations is not a difficult matter. If the

date and hour of each observation and the temperatures are recorded the reductions can be made when observations have been sent in. An aneroid (and a mercury barometer for that matter) measures the atmospheric pressure, *not* the relative or absolute height of the station; but surveying aneroids are calibrated in feet of altitude as well as in inches of mercury, and the difference of two readings is an indication of the difference of level of the stations. They are normally compensated for the varying density of air at different temperatures, so that theoretically the varying temperature of the *instrument itself* should not affect its reading so long as the *atmospheric* temperature and pressure remain constant. This however, is far from being the case in practice, as may be seen by heating up an instrument. Furthermore a jar may easily cause a large index error. Where difference of altitude can be quickly measured several times in succession, without exposing the instrument to large changes of temperature, results correct to a few feet can be obtained; where however the readings are spread over a day's work in the sun discrepancies of as much as 100 feet may be found after reduction, even in the work of a skilled observer, especially in the intermediate readings during the day's march. There are two corrections to be made:—

(*a*) for the alterations of the atmospheric pressure during the period of the readings, including the diurnal variation;

(*b*) for the temperature of the air.

As regards the former, the best method is to have two aneroids, one of which is kept at one point and read at intervals, so that any rise or fall may be allowed for in the readings of the other. This however is seldom practicable, and the alternative is to apply the average correction for the diurnal variation for India given in Molesworth's "Pocket Book" under the heading "Aneroid levelling." For all practical purposes one inch may be taken as equivalent to 1,000 feet. This correction may amount to as much as 50 feet either way. It neglects any actual changes due to depressions, etc., which can however be obtained from the daily weather reports; but if readings are taken at the start of each day those are seldom of importance.

The temperature correction depends on the added temperatures at the two stations of observation, so these should be recorded at each reading. The difference in height of the readings (assuming the aneroid to be graduated in feet) has to be multiplied by a constant which will be found in Molesworth (loc. cit), varying from unity at $T+t=64°$ F. up to 1·137 where $T+t=188°$ F.

As an example is always preferable to a reference to rules and text books the records and reduction of part of an actual survey are given in Appendix III.

CHAPTER IV.—POWER AND ITS USES.

14. *Census of power used in India.*—In connection with the hydrographic surveys and coal conservation enquiries in various parts of the world endeavours have been made to ascertain the approximate amount of power used. Thus in the Preliminary Report of the Water Power Committee of the Conjoint Board of Scientific Societies we find (page 2) :—

"It is impossible to estimate with any pretentions to accuracy the power now being used in the various countries of the world. Independent estimates, based on such data as are available, tend however to show that it is of the order of 120 million horse power made up approximately as follows :—

World's factories, including electric lighting and street railways . . .	75	million horse power.
World's railways	21	" "
World's shipping	24	" "
TOTAL .	120	" "

This includes all steam, gas and water power.

Of the 75 million horse power used for factories and general industrial and municipal activities, a rough approximation of the most probable distribution would appear to be—

United Kingdom	13	million horse power.
Continental Europe	24	" "
United States	29	" "
British Dominions and dependencies . .	6	" "
Asia and South America	3	" "

Enquiries were set on foot at an early stage of this investigation to ascertain the approximate power installed in various industries and localities in India. Previously this had only been done for electric power, where it was found in 1917 that the total amounted roughly to 215,000 kilowatts or say 285,000 electrical horse-power, of which 36 per cent. was obtained from water power*. The total units generated amounted to only 550 millions. For demonstrating the backward state of electrical development the following comparison with other parts of the Empire will be of interest. The watts installed per head of population† are as follows :—

	Watts per capita.
Canada	118
Australasia	62
South Africa	57
British Isles	33 = 1 ordinary glow lamp.
India	Under 1

If population be a poor criterion let the area per kilowatt ($1\frac{1}{3}$ horse power) installed speak :—

British Isles . . .	$\frac{1}{12}$ square mile per kilowatt.	
South Africa . . .	1·4 " " " "	
Canada . . .	3·5 square miles per kilowatt.	
India . . .	7·6 " " " "	
Australasia . . .	11 " " " "	Largely uninhabited.*

The following figures are now available for the power of all kinds in use in certain parts of India at present; they are only approximations and are very incomplete. They have been compiled by the Directors of Industries or Controllers of Munitions for the most part, and it has been impossible to enter

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* List of Electrical Undertakings in India, 1916-17.

† "A project for providing the Punjab with a cheap supply of Electric Power"; F. L. Milne, A.M.I.E.E. (Proceedings of the Punjab Engineering Congress, 1919.)

the full details here. Recommendations are however made for the completion of this necessary work, in para. 31 *infra*.

Assam (all forms of power)—	Brake horse power.
Cachar	4,940
Darrung	2,980
Haligang	600
Kamrup	290
Lakhimpur	5,268
Sibsagor, Goalpara, Khasia and Jaintia Hills, Nowgong	4,619
South Sylhet	700
Sylhet	3,153
TOTAL	22,550

Bengal—

The returns compiled in this area, by the Controller of Munitions, are particularly comprehensive in their details and are accompanied by a map showing the totals in each district *exclusive of the Calcutta Industrial area.** A few returns have not yet been received. The results are as follows :—

	Brake horse power.		Brake horse power.
Bakarganj	42	Malda	12
Birbhum	34	Midnapore	2,750
Burdwan	15,371	Murshidabad	80
Calcutta area*	excluded	Mymensingh	45
Chittagong	697	Nadia	145
Dacca	874	Pabna	26
Darjeeling	1,824	Rajshahi	6
Dinajpur	25	Rangpur	29
Faridpur	12	Tippera	239
Jalpaiguri	3,109		
		TOTAL	25,318

The Calcutta Industrial area has the following known power, *viz.* :—

Jute Mills about	85,000	b. h. p
Cotton " "	75,000	"
	160,000	"

In addition it contains the following number of works, of which the power has not been estimated :—

Bone Mills	8	Miscellaneous	9
Chemical works	11	Oil Mills	26
Cotton presses	3	Paper Mills	2
Distilleries	2	Rice Mills	7
Engineering works	36	Rope works	5
Flour Mills	11	Saw Mills	4
Glass work	1	Ship yards	8
Ice Factories	2	Soap works	7
Jute presses	19	Sugar Factories	1

These 162 factories may safely be assumed to have an average of not less than 100 b. h. p. installed, or a total of 16,200 b. h. p.

Bihar and Orissa—

Except for the coal mines, which obviously do not require water power, there are not many factories in this province ; and the low cost of coal and of waste gases in the steel works would, in any case, militate against the substitution of water-power. The indigo industry employs very little plant and that only for a very short period annually. There are sugar factories, mostly small, in Darbhanga, Saran, Champaran and Muzaffarpur Districts; but their working season is only 6 months, and steam is in any case required for extraction of the juice. Small oil mills are scattered over the Province. Monghyr District contains a tobacco factory using 200 horse-power and the East India Railway Workshops using 2,000 horse-power. Darbhanga District has the Bengal and North-Western Railway works using 125 horse-power and in addition to the sugar mills mentioned above there are proposals for large rice mills. These however, following Rangoon practice, will probably use their own refuse for steam raising.

* The Calcutta Industrial area [illegible]

Bombay (10 out of 14 districts; Bombay City not included)—

	Brake horse power.
Ahmednagar	773
Belgaum	600
Bijapur	1,900
Dharwar	1,031
East Khandesh	7,975
Kanara	25
Kolaba	90
Nasik	560
Poona (including electricity)	1,830
Ratnagiri	...
Satara	140
Sholapur	8,020
Thana	5,906
West Khandesh	3,422
TOTAL	32,872

As there are about 10 times as many Cotton mills in Bombay and Ahmednagar as in Bengal, it may safely be assumed that the power used in those districts for this purpose is not less than about 750,000 b.h.p.

A considerable part of this power is supplied by the Tata hydro-electric works.

Burma—

The Electric Inspector reports that all the existing large mills use their own refuse, chiefly paddy husk and sawdust, as fuel; they are therefore not interested in water power supply. The Rangoon Electric Tramways also use paddy husk; at present the clinker, which is almost pure silica, finds no market, but it may be used hereafter for glass making. In these circumstances a census of power is not of much use, and as the letters of the Deputy Controller of Munitions on the subject were not replied to no figures are available. It is estimated that the Cinchona districts of Tavoy will require about 750 horse-power and the mining districts 2,000 horse-power. There may be a demand in the Toungoo area for 600 horse-power for pulp manufacture. The oil fields in Yenangyoung and neighbourhood will require some 15,000 horse-power but this is being arranged for by the companies concerned, who will use their oil for fuel. This is the case now, but at present every well has its own steam engine, with oil-fired boiler, and a comprehensive electrical distribution scheme will effect great economy in fuel consumption.

Central Provinces—

	Brake horse power.		Brake horse power.
Akola	4,936	Nagpur	6,173
Amraoti	4,504	Nimar	2,665
Balaghat	50	Narsinghpur	54
Bhandara	25	Raipur	50
Bilaspur	110	Saugor	20
Buldana	3,548	Seoni	60
Chanda	712	Wardha	5,839
Chhindwara	85	Yeotmal	1,900
Hoshangabad	605		
Jubbulpore	1,420	Total	32,773
Mandla	14		

Madras—

DISTRICT.	Brake horse power.	
Bellary	3,232	
Chingleput	1,783	70 rice mills; 6 irrigation plants; 2 water works; 2 others.
Chittoor	217	7 rice mills; 3 irrigation plants; 1 metal works.
Cuddapah	1,162	31 gins and decorticators; one irrigation plant, 2 water works; 3 others.
Ganjam	591	7 rice mills; 6 others.
Godavery	3,220	59 rice mills; 4 ginning.
Guntur	2,096	24 rice mills; 15 ginning; 4 others.
Kistna	7,532	
Kurnool	1,388	5 presses; 26 ginning; 2 oil mills; 5 others.
Malabar	4,149	16 tea factories; 12 brick and tile; 35 various.
Madura	812	
Nellore	917	21 rice mills; 5 others.

Madras—contd.

DISTRICT.	Brake horse power.	
North Arcot	1,810	
Ramnad	1,588	25 rice mills; 9 ginning; 1 electric.
South Arcot	1,227	58 irrigation plants; 35 rice mills; 7 others.
Tinnevelly	4,824	20 ginning; 6 rice mills; 18 others.
Trichinopoly	1,149	47 rice mills; 18 irrigation plants; 4 others.
Vizagapatam	1,871	9 rice mills; 17 various.
TOTAL	39,568	

North-West Frontier Province—

No returns received.

Punjab. (Steam only)—

	Brake horse power.
Ambala	1,020
Amritsar (excluding electricity and oil)	1,563
Bhitak	150
Dera Ghazi Khan	186
Gujranwala	781
Gurdaspur	500
Gurgaon	516
Hissar	825
Jhelum	520
Karnal	558
Lahore (excluding electricity)	2,333
Ludhiana	1,285
Lyallpur	2,491
Multan	1,060
Muzaffergarh	126
Rawalpindi	525
Shahpur	881
Sialkot	284
Simla (excluding electricity)	130
TOTAL	15,734

United Provinces—

	Brake horse power		Brake horse power.
Agra	2,810	Jallaun	387
Aligarh	1,585	Jaunpur	...
Allahabad	1,648	Jhansi	255
Almora	84	Kheri	52
Badaun	272	Lucknow	2,991
Bahraich	203	Mainpuri	306
Banda	269	Meerut	702
Barabanki	186	Mirzapur	338
Bareilly	1,297	Moradabad	1,138
Benares	1,797	Muzuffernagar	317
Bijnor	243	Muttra	810
Bulandshahr	1,458	Naini Tal	432
Cawnpore	8,264	Nowgong	58
Dehra Dun	485	Philibhit	535
Etah	500	Partabgarh	65
Etawah	780	Rai Bareilly	60
Farukhabad	861	Saharanpur	1,176
Fatehpur	106	Shahjehanpur	940
Fyzabad	238	Sitapur	323
Gonda	341	Sultanpur	21
Gorakpur	2,110	Unao	506
Hamirpur	77		
Hathras	1,627		
Hardoi	350	Total	38,548

This is exclusive of public electric supply and Military Works power stations but [illegible]

Summary—

	Brake horse power.
Assam	22,550
Bengal	25,318 exclusive Calcutta area.
Calcutta area	170,200
Bihar	2,325 apart from collieries, etc.
Bombay Presidency	32,572
Bombay City area	750,000
Burma	17,750 exclusive of rice mills, etc.
Central Provinces	32,773
Madras	30,568
North-West Frontier Province . .	...
Punjab	15,734 steam only
United Provinces	38,548
GRAND TOTAL .	1,153,638

15. *Further uses for power.*—For a full discussion of the new industries which may arise in India, if cheap electric power is available, the Report of the Indian Industrial Commission must be referred to. The "Industrial Handbook 1919" issued by the Indian Munitions Board also merits close study. Among these industries may be mentioned the electric smelting of indigenous iron ores and the electrical production of steel and its alloys; electric welding, now extensively employed; the production of aluminium from alumina, prepared from the local bauxite deposits; the manufacture of calcium carbide and its innumerable derivatives; the direct fixation of atmospheric nitrogen into the nitrates of commerce; the electrolytic production of chlorine gas and the preparation of phosphorus and of abrasives like carborundum. All these processes are in actual use in various parts of the world where the raw materials and the power are found. The map in this report has marked on it information regarding the occurrence of certain of these raw materials. In some cases the process is electro-chemical, in others electro-thermal, but in all cheap power and large scale production are essential to success. The following further extract from the Preliminary Report of the British Water Power Committee will emphasize what has been done and what may in future be done in some of these matters:

"Electro-metallurgy and electro-chemistry have rendered it possible to handle materials not workable by any other means; have made available new materials; and have greatly cheapened the production of many important materials of wide use. Aluminium, calcium carbide, chromium, cyanide, silicon, carborundum, are products rendered commercially possible only by electrical processes, while alkalies, hypochlorite, phosphorus, magnesium, and sodium nitrate are produced most economically by such processes. Great developments have recently taken place in the production of electrolytic copper and zinc and in processes for the electric smelting and refining of metallic ores.

All these processes demand relatively large amounts of energy. The world's production of calcium carbide, for example, was 340,000 tons in 1913, requiring 400,000 continuous electric horse-power for its production, while the energy used at the end of 1915 for electric furnaces in the United States alone was approximately 300,000 electric horse-power.

Nitrogen Fixation.—In the utilization of atmospheric nitrogen for the production of nitric acid and the manufacture of nitrates, great developments have taken place during the last decade, and in Norway alone over 400,000 electric horse-power is now absorbed in its production. The world's annual consumption of nitrogen in its various combinations is about 750,000 tons, representing a value of about £50,000,000 and this demand is increasing yearly. Four-fifths of this supply has been produced hitherto from natural nitrate deposits, but in view of the rapid depletion of these deposits, and of the diminution in the fertility of most of the great wheat and cotton-growing areas of the world, the production of artificial fertilizers by one or other system of nitrogen fixation must, in the near future, become a question of national importance.

At the present time the world's consumption of fertilizers amounts to close upon 6,000,000 tons per annum, and this will probably be doubled within the next 20 years. To-day, the efficiency of the electrical production is low, amounting in the case of calcium nitrate to about three-quarters of a ton per electric horse-power year. By adopting the cyanamide process the consumption of energy may be cut down to about one-fourth, but even in this case the production of the equivalent of 12,000,000 tons of fertilizers per annum would require 4,000,000 continuous electric horse-power.

It is estimated that the 200,000,000 acres of arable land in Canada alone may ultimately require some 10,000,000 tons of nitrates per annum to maintain their fertility, and this in itself would necessitate the absorption of an appreciable portion of the whole hydraulic energy of the Dominion.

When to those demands are added those of India, Australia and Africa, it is evident that the fertilizer demand of the Empire will in itself call for an enormous supply of energy."

Apart from ordinary town supply for electric lighting, heating and fans and supply to tramways and railways (especially hill lines) for traction purposes, there are many other industries in which electric power would be welcomed if it could compete with other forms, and in any area where reasonably cheap hydro-electric development is possible within transmission distance this successful competition is simply a matter of relative costs. To take one instance, in a comparatively small area of the Duars, within easy reach of water power, (*i.e.*, the Jaldaka q.v., in chapter 6), it is estimated that fuel equivalent to a working load of about 100,000 horse-power, is used in the tea factories; partly for the production of power from steam engines, but mainly for drying purposes with hot air and fans. Both the motive power and the hot air can be obtained electrically; it is merely a question of comparative costs. Other tea districts are similarly situated. Again, the cotton mills of Bombay are now mostly driven by electric motors fed from the Tata scheme, which have replaced steam engines. There may, given cheap enough power, be a similar opening for jute mills, oil mills, timber working, sugar production, paper pulping and other industries. The two sets of rival conditions that make or mar a hydro-electric project will presently be examined; namely, the competition between fuel and water and that between the freight on materials and the transmission of power.

As regards pumping for irrigation purposes, somewhat wild suggestions have been made under the impression that "water power costs nothing." It is very unlikely that such pumping will pay on any water rate that could be demanded, where the lift is at all great. It has already been shown in para. 1 that under favourable conditions the overall efficiency from water to electrical horse-power at the generator terminals will be about 85 per cent. By way of example let a gross pumping head of 100 feet, from the source of water to the distributing irrigation channel, be assumed; this is probably over the economic limit, but as the power taken is practically proportional to the head the example can be reconstructed for any lower value. Assume further that 2 cubic feet per second (*i.e.*, 12½ gallons or 125 lbs. per second) is to be pumped up this 100 feet, absorbing 22·7 theoretical water horse-power. A modern turbine pump in these circumstances will have an efficiency of 75 to 77 per cent. and will require about 30 brake horse-power to drive it. The electric motor giving this mechanical power will have an efficiency of about 90 per cent. so that it will take some 33·2 electric horse-power at its terminals. If a transformer is necessary the input into it from the line will then be about 34·2 electric horse-power. If the transmission losses are taken at 10 per cent. the line must be fed at the power station with 38 electric horse-power. If there is no transformer here the generator will supply this amount of power, and on the overall efficiency assumed in this report it will use 44·7 theoretical water horse-power. *Thus the overall efficiency from water falling to water raised will be practically 50 per cent. under the best conditions.* The capital charges on the cost of the motor with its housing, its pump and its pipes, together with a share of the charges on

the distribution system and power station, have to be met from the additional revenue due to the supply given. If the lift of the pump were 10 feet instead of 100 then ten times the amount of water could be pumped for the same power, and ten times the acreage irrigated. The proposition would then become more practicable.

Experimental work in sub-soil pumping by means of tube wells has for some years been in progress at Amritsar, Punjab; see table 2. Sir John Benton, K.C.I.E., late Inspector General of Irrigation, took up the matter with keen interest and the work has been in the hands of Captain John Ashford, M.I.C.E. The late Mr. Barlow visited this canal fall development a week before his death, and was greatly struck with the possibilities of the method for adoption in the United Provinces, where the present intensity of cultivation is less than 25 per cent., of the total area. Canal falls abound, as will be seen in Appendix 14, and sub-soil water is plentiful. Mr. Barlow hoped to see experimental work carried out in this area.

16. *Fuel and water power.*—It has already been stated that the commercial possibilities of any hydro-electric scheme depend on two factors, the capital cost of the scheme on the one hand and the cost of the competing fuel on the other. Comparing a steam or oil-driven electrical plant with one water-driven, the latter is almost invariably much more expensive to construct; and all it saves is the cost of fuel, which is only one factor in the cost of generating power. Staff and stores, office and legal expenses, repairs and depreciation are incurred in both. Thus while the actual comparison will be between the price at which electricity can be sold in both cases the real criterion of success is whether the capital charges for interest and depreciation on the *excess* cost of the water power undertaking will be substantially less than the cost of the fuel used by the other. The following extract from an article by the present writer in the Indian Munitions Board's "Industrial Handbook, 1919," reprinted from the Bengal Economic Journal, 1918, on "The future of hydro-electric power in India" will repay study.

"It is obvious that large capital expenditure is necessary on the hydraulic development; furthermore as water power must be developed where it is found a long transmission line is often necessary. For these reasons the total cost of construction is almost invariably higher than that of a steam-driven plant of the same capacity; and the annual capital charges for interest and depreciation are correspondingly higher.

"Against this may be set the fact that the running costs of such a station are relatively low, as no fuel is involved. The total cost of running does not depend to any appreciable extent on whether the plant is fully or only lightly loaded; it is practically *a fixed sum per annum*; so that the cost *per unit* is practically proportional to the total number of units generated. This is not so with fuel-consuming stations. Every extra unit generated then involves the consumption of a definite amount of fuel with a definite cost; and while the total cost rises with the number of units generated and the cost per unit falls somewhat, the latter is by no means proportional to the total units. In any particular case therefore the practicability of a hydro-electric scheme depends on the cost of fuel in the locality where the power is wanted.

"To take an example, assume a plant of 5,000 kilowatts capacity is required at a certain place where sufficient water power exists within transmission distance. Assume the total cost of the hydro-electric scheme and transmission line to be Rs. 50,00,000. (It might be very much less in favourable circumstances.) Taking interest and depreciation together at 10 per cent. the annual cost on this account will be Rs. 5,00,000.

"Let the cost of a steam plant of the same capacity, built where the power is actually needed, be assumed to be Rs. 15,00,000 with similar annual capital charges of Rs. 1,50,000. Now if for simplicity it be assumed that the annual charges for wages, stores, repairs and supervision are the same in both cases (an assumption near enough to the truth) there will be the difference between Rs. 5,00,000 and Rs. 1,50,000 or Rs. 3,50,000 to set off against the cost of fuel for steam raising. Under the ideal conditions of large electro-chemical works this plant, allowing 1,000 kilowatts to be kept for spare and therefore 4,000 for work, would generate about 28 million units (80 per cent. load

factor). Under ordinary industrial conditions the output would be less than half this, or say about 12 million units. Clearly therefore not only the cost of coal but also the load factor of the plant (*i e.*, in non-technical language the ratio of its actual to its possible output) is of immense importance. If it is assumed that the low amount of only 2 lbs. of Indian coal will be required per unit, with modern plant of large size, the consumption would be 25,000 tons for 28 million and 10,700 tons for 12 million units. As the amount available to make the costs just balance out between steam and water power is Rs 3,50,000 it follows that with the larger output coal at Rs. 14 per ton would absorb this amount, while with the smaller output the figure would be nearly Rs. 33. From this example (in which the figures are not meant to represent estimates) it will be inferred that as the load factor rises towards the ideal limit the advantage of hydro-electric power increases. Bearing in mind the vast difference in the cost of fuel in different parts of India, due mainly to railway freight, it will also be seen that the distance from fuel supplies is a very material factor. With coal under Rs. 10 per ton it is doubtful if water power could ever compete unless (rare combination) it existed right on the spot and could be developed exceptionally cheaply. On the other hand, with fuel at over Rs. 30 a ton, water power would generally prove cheaper and, for a well-sustained industrial load, invariably. Between these limits proper estimating would be necessary."

A map* has been prepared in the Coal Controller's office to show very roughly the cost of coal at certain places in India which are on the railways; this cost is the selling price at the pit's mouth plus railway freight. Clearly at any distance from the railway the cost will be increased, and that heavily, by the cost of carriage by road. A point which it is desirable to emphasize here is that in certain circumstances water power may be of immense value whether it be within reach of cheap fuel or hundreds of miles from it; *i.e.* where it is required *not* for existing industries but for a new electro-chemical or electro-thermal industry. These, working almost continuously at full load (*i.e.*, with a load factor of 90 per cent. or more), *must* go where there is cheap water power; and when 50,000 horse-power or more is being developed a very large capital expenditure on dams and other hydraulic works can readily be faced.

17. *Freight and transmission of power.*—The popular fallacy that "water power costs nothing" has been examined as regards the initial cost of the plant in the previous paragraph. The cost is generally further increased by that of transmission lines, since water power is seldom situated precisely where it is required. Either the power must be carried to the industry or the raw material and finished products of the industry must be taken to and from the power. Both ways cost money. The following further excerpt from the article in the Munitions Board's "Industrial Handbook, 1919," quoted in the preceding paragraph, explains the matter more fully.

"Where electro-chemical industries on a large scale are in question it is essential that the price of the power shall be very low if the manufactured product is to compete with that produced elsewhere. The cost of power is of course only one item amongst many in determining the sale price of the finished article, but it is a very important item—perhaps second only to the freight of the raw material to site and the finished product to market. Where the conditions of the hydraulic development are such that construction on a large scale is reasonably cheap; where the locality is such that the freight of the plant and materials thereto is low; and where the length of transmission to the factory is reasonable; power can probably be delivered at about one-tenth of an anna per unit including all charges. Indeed, if the cost is much higher than this, the proposition becomes untenable. Obviously the undertaking must be on a fairly large scale to be of any use. The larger the individual units of plant are made the smaller becomes their prime cost per kilowatt and the higher their efficiency. The various electro-chemical industries are favourable to these low costs as they are practically continuous processes, utilizing the whole plant to almost its utmost capacity throughout the year.

* Not received at the time of going to Press.

"In considering the value of sites that may possibly meet these ideal conditions the first point to consider is undoubtedly that of freight and carriage; for it has a triple application. In the first place the raw material must be brought to the site, unless already on it; secondly the finished product must be taken to its market; thirdly the plant must be delivered at the power house. Cases are known where the carriage of plant over 20 miles of mountain roads cost more than its freight from England to the railway terminus. Cheap power is useless if the saving is swallowed up in expensive freight. Where bulky raw material has to be brought to the factory and sent back finished the obvious course is to build an electric railway from the nearest terminus, seeing that cheap power for working will be available. In order to get the plant to the power house there must be a road, and this road should be built so as to afford a suitable track for the subsequent railway. During the construction period a light line worked by steam will probably pay as against other methods of transport of the plant The tendency of the man who put his travelling crane up after erecting his plant is often only too apparent in these matters, and carriage by coolie is seldom cheap.

"From small beginnings electrical transmission of power has now reached the stage where it is possible to have the factory 250 miles or more from the power station, and it would be unwise to say that the limit of high pressure has been reached. In the case of water power from mountainous country there may be insuperable difficulties of ground or cost in laying out a railway to the site, though the plant can be transported there Even if these difficulties do not exist, if the raw material of the industry is within the limits of transmission it will probably prove cheaper to erect a long transmission line rather than a railway, which may use more power than will be lost in transmission. It is simply a question of estimating which method gives the cheapest finished product. Either the material can be brought to the power house; or the power to the factory; or a combination of both methods may be the best. Mountainous country has one great asset for transmission in that the ridges form nature's own supports for the lines; with comparatively small towers the valleys offer plenty of room for the dip of the wires on long spans. It also follows that by reducing the number of points of support, by the use of long spans, there are fewer points at which damage from lightning can occur. The loss in transmission can be made almost as large or as small as the designer chooses, according to the size of the wires used; ordinarily about 10 per cent. is allowed. Where steam is used to generate the power the correct loss can be calculated according to Kelvin's law and its modifications, such that the capital charges on the conductors balance the cost of the power lost in them. If more power is required more generating sets can be added indefinitely. With unlimited water power the cost of the lost power is of secondary importance, and larger losses may be advisable than in the former case. On the other hand, if the available power is likely to be all required—and this is generally the case—the line losses may have to be reduced to very low amounts, since every unit available for the factory is of value."

The cost of transmission lines operates detrimentally in two ways; first by increasing the prime cost and consequent capital and upkeep charges, and secondly by decreasing the available energy for sale at the far end, owing to losses in the line. These line losses can be made almost as large or as small as the designer chooses, but if they are made small it is by adding more copper wire, or larger wires, so that this reacts on the prime cost. The statement is often made that a long transmission line only means a loss of about 10 or 15 per cent. of the power generated; true, but it may increase the economic selling price vastly more. It has been recorded (Electrical Times, 55, January 2nd 1919) that the cost of transmission at Niagara, which extends to a distance of 250 miles, ranges from 22 to 86 per cent. of the total cost of the power delivered, according to distance. These figures would be greatly improved on under modern conditions, at any rate with pre-war prices, but they serve as an indication that water power does not "cost nothing."

18. *Admissible cost of hydro-electric Schemes.*—While it must never be forgotten that generalities and averages in engineering problems are

apt to be most misleading it is nevertheless desirable to give some indication, however it may contravene this canon, of the permissible cost of hydraulic developments. A table showing the cost of the schemes now in operation, including power house and plant but *not* transmission, is given in paragraph 23. Obviously, from the two preceding paragraphs, as the cost of fuel rises the permissible cost of water power rises too. But, against this, the further the power has to be transmitted, the greater will the capital cost and losses become. Arising out of both of these truisms it is clear from what has gone before that, other things being equal, fuel has an advantage when the plant is not fully loaded most of the time, *i.e.* when the load factor is bad, while on an exceptionally good load factor water power has an immense advantage. We have then to combine these factors:

Cost of fuel,
Cost of transmission,
Load factor.

To make the matter clear an example may be given, but *it must not be taken as an estimate*; it is full of assumptions, none of which can be laid down as facts. Assume that 10,000 electrical horse-power is required for use in a certain district, and that the alternatives are steam and water power, each the most modern of its kind. Any other power of the same order would come to much the same thing. The steam power station would be placed as a matter of course in the most favourable site within the area; the hydraulic plant would go where nature placed it. Three cases may be assumed, *viz.*, water power on the spot; transmission of 50 miles; transmission of 100 miles. As regards fuel three representative prices will be taken, *viz.*, Rs. 8, Rs. 16 and Rs. 24 per ton for Bengal coal of about 11,000 British Thermal Units calorific value; the first is about the price at the radius from the coal fields of Calcutta, on the railways, and the other prices will be found further off. Four characteristic load factors will also be taken, *viz.*, 20 per cent., 40 per cent., 60 per cent. and 80 per cent. So far the assumptions are admissible. In order to reduce the matter to graphic curves let it now be assumed that the cost of the power station, with all the plant within it, is sensibly of the same order for the steam and water power plant; excluding of course the transmission line and the hydraulic development beyond the power station. The distribution lines, etc., for employing the power at its destination, and the power lost in them, will be unaffected to all intents by the method of generation, and may also be left out of account. Then the cost of fuel on the one hand has to be set off against the cost of the hydraulic development on the other. With modern boilers and steam turbines, using Bengal coal, an average consumption of 1½ lbs. per electric horse-power hour generated may be taken as an extremely good figure, though in a super-station it might be excelled on a high load factor. Using this consumption at each of the stated load factors and prices, though actually the consumption on a poor load factor would be somewhat higher, the following table gives the cost of fuel per annum in column 3.

This has then been capitalized in column 4 at the round figure of 10 per cent. for interest and depreciation to show the sum in lakhs of rupees which can be spent on a hydraulic development on the same spot. Dividing by 10,000, column 5 gives this as the permissible capital cost per electric horse-power installed, where there is no transmission.

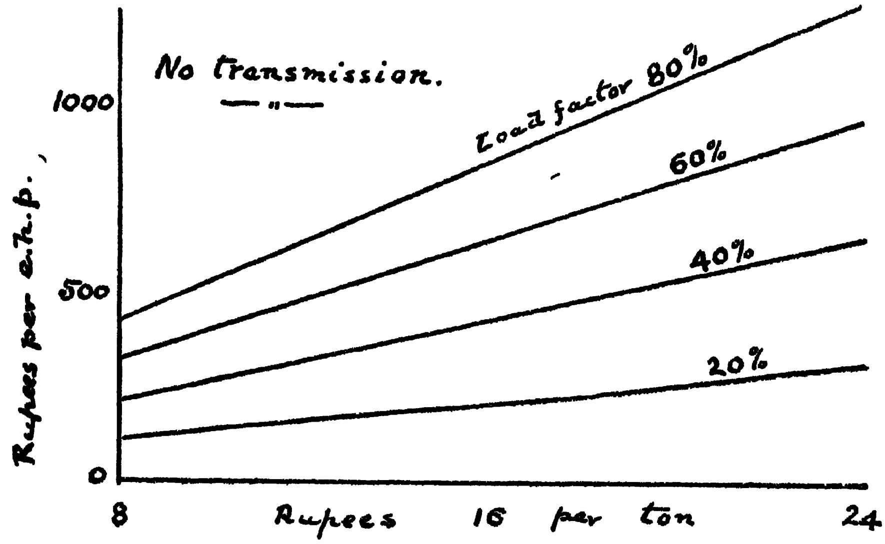
Next, a transmission line of 50 miles is assumed, with a loss of power of 10 per cent. The cost of the line is placed at the reasonable amount of Rs. 10,000 per mile, or 5 lakhs, which is deducted from column 4 and the result is given in column 6. But to deliver 10,000 electric horse-power while losing 10 per cent. the plant must be of 11,200 electric horse-power and the extra capital cost of this at Rs. 100 per electric horse-power (1·2 lakhs) is further deducted in column 7. The values so obtained, divided by 11,200, give the permissible cost of the hydraulic development per e. h. p. installed in column 8.

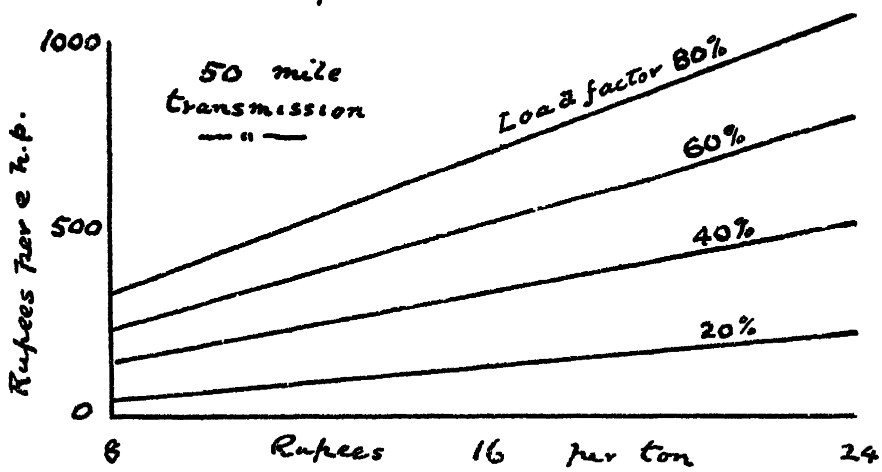
For the transmission of 100 miles the same procedure is adopted in columns 9 to 11, with a line loss of 15 per cent., an extra capital cost of 10 lakhs for the line, and a plant of 11,750 electric horse-power installed.

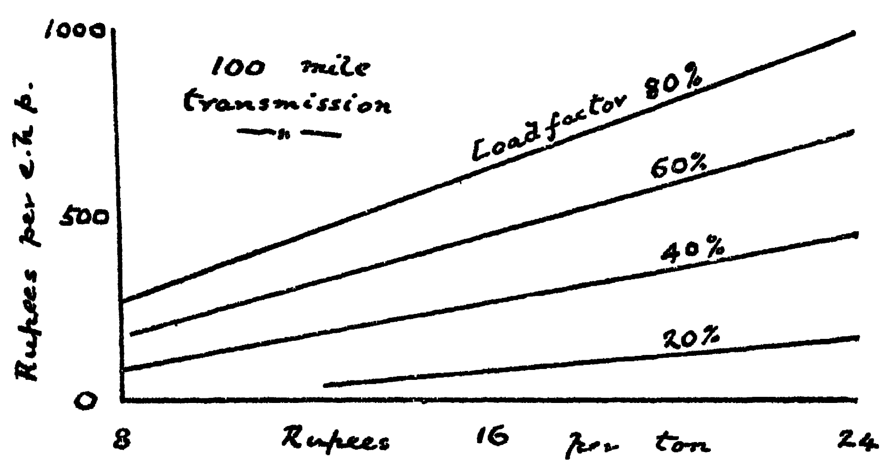
Table 1.—Admissible cost of Hydraulic Development.

Load Factor.	Cost of fuel per ton.	Cost of fuel per annum.	Capitalized value at 10 per cent.	WATER POWER AT SITE; NO TRANSMISSION. Admissible capital cost of hydraulic development only per electrical horse-power installed. 10,000 e. h p.	TRANSMISSION 50 MILES. Column 4 less 5 lakhs for cost of transmission	Column 6 less 1·2 lakhs cost of additional plant for transmission losses.	Admissible cost of hydraulic development only per electrical horse-power installed 11,200 electric horse-power.	TRANSMISSION 100 MILES. Column 4 less 10 lakhs for cost of transmission.	Column 9 less 1·7 lakhs for cost of additional plant for transmission losses.	Admissible cost of hydraulic development only per electrical horse-power installed 11,750 electric horse-power.
Per cent	Rs.	Lakhs.	Lakhs.	Rs.	Lakhs.	lakhs.	Rs.	Lakhs.	Lakhs.	Rs.
1	2	3	4	5	6	7	8	9	10	11
20	8	1·06	10 6	106	5·6	4·4	39	0·6	...	...
	16	2·12	21·2	212	16·2	15·0	134	11·2	9·4	80
	24	3·18	31·8	318	26·2	25·0	223	21·8	20·1	171
40	8	2·12	21·2	212	16·2	15·0	134	11·2	9·4	80
	16	4·24	42·4	424	37·4	36·2	322	32·4	30·7	261
	24	6·36	63·6	636	58·6	57·4	511	53·6	51·9	441
60	8	3·18	31·8	318	26·2	25·0	223	21·8	20·1	171
	16	6·36	63·6	636	58·6	57·4	511	53·6	51·9	441
	24	9·54	95·4	954	90·4	89·2	795	85·4	83·7	712
80	8	4·24	42·4	424	37·4	36·2	322	32·4	30·7	261
	16	8·48	84·8	848	79·8	78·6	700	74·8	73·1	622
	24	12·72	127·2	1,272	122·2	121·0	1,080	117·2	115·5	980

Plotting the values so obtained they become more intelligible. The cost of storage works, canals, regulating reservoirs, pipes, etc., varies so enormously in various instances that each case must be judged on its merits. It is clear, however, that with bad load factors and cheap coal no water power can compete, while at the other extreme water power will generally have the field to itself.







To bring home the fact that the examples given must not be relied on except to establish a principle it may be pointed out that the extremely low coal consumption assumed per electric horse-power hour is nowhere obtained in India at present, and in very few places elsewhere ; it represents the best side of the case for fuel. If an average consumption of 3 times the amount, or 4½ lbs. per electric horse-power per hour, be assumed it will still be better than most Indian power stations can command. Load factors on these stations are mostly of the order of 40 per cent. If the same process of calculation be adopted for these new values the result is to raise the permissible cost of hydraulic develop-

ment considerably. On the 3 assumed costs per ton the outlay may now be Rs. 636, Rs. 1,272 and Rs. 1,908 for a station at site; Rs. 510, Rs. 1,070 and Rs. 1,674, with a 50 mile transmission: Rs. 440, Rs. 980 and Rs. 1,520, with a 100 mile transmission. The curves can, if desired, be extended to show these new limits; and the facts of any specific case will probably then lie within the area of the limits of each.

CHAPTER V.—CONTROL OF WATER POWER.

19. *State control and assistance.*—The British Water Power Committee expresses a strong opinion in favour of State control of all water power, and its argument must be given in full :

> "The considerations already outlined would indicate that the conservation and utilization of the water power resources of the Empire is likely to be one of the most important problems in our political economy. The solution of this problem involves many complex questions of law, of administration, and of engineering and economic investigation, if the public interest is to be best served by the development. In view of the immensity of the interests involved, it is urged that nothing short of statutory control of these developments is desirable. The exact method of control is not for the Committee to suggest. So far as is possible private enterprise should be encouraged, but under conditions which would prevent the perpetual rights being lost to the community. In this connection it is worthy of note that Canada and New Zealand have State control over the majority of their water powers, and that in all provinces in India there are Canal Acts which expressly lay down that Government is entitled to use and control for public purposes the water of all rivers and streams flowing in natural channels. In the case of Australia, each State has enacted lengthy legislation in relation to water conservation, but no special clauses appear in respect of developable water power. It is also suggestive that the Administration in Washington is at present taking steps to control the development of water-powers on all public lands and navigable streams in the United States; that, in spite of the revolution in Russia, the provisional Government has recently appointed a Water Power Committee, with absolute control over the development of all water power schemes in the Empire exceeding 300 horse-power; and that the Austrian Government has, during the past session, introduced a bill for the promotion of hydro-electrical development, giving the State the right to acquire any undertaking after the expiration of 25 years, and at the end of any subsequent period of five years.
>
> "It should be recognized, however, that while it is essential that the State should have the right of ultimate purchase, the period of such purchase should not be unduly short or the terms too onerous. It will be remembered that such legislation had the effect of severely handicapping the electric power and lighting industry in the early days of its development."

During the course of this preliminary enquiry the question of the policy to be adopted was discussed on various occasions with public officers, firms and individual engineers. A policy suitable for one part of India may be the reverse elsewhere. Thus in Bombay it is recognized that the chain of great projects extending down the Western Ghats, from the Andhra Valley to the Koyna River, covers all likely power requirements for a long time to come. Here the enterprising firm of Messrs. Tata can provide both the capital, the business organization and the engineering talent required. The help of Government however is required in such matters as land acquisition and water rights, transmission routes and so forth.

Elsewhere it is generally considered that more direct Government assistance will be required. At present there is a vicious circle of industries that require power and power looking for an assured outlet; and neither side is inclined to make a move unless certain of the co-operation of the other. An example already exists of established water power going a-begging, within transmission

reach of a considerable demand, and whatever the reasons may have been that led to this *impasse* it has undoubtedly had a deterrent effect on similar enterprise elsewhere. There may be cases where the carrying out of a project by Government may be advisable, if investigation proves that the indirect benefit to the country of cheap power will counterbalance a comparatively small return on the capital invested in the power scheme. Generally however the trend is rather in the direction of a Government guarantee of interest during construction and of a minimum return thereafter, which would be recouped, in successful undertakings, by some form of sliding scale or profit sharing, or both. In certain provinces indeed it seems likely that the capital itself may have to be provided by Government as a loan, on similar terms to municipal loans, with a period of repayment equal to the probable economic life of the plant, *i.e.*, nearer 20 than the customary 30 years ; but here again a guarantee of a minimum interest on the one hand and a share of the excess profits over a moderate return on the other hand may be essential if the dependant industries are to be fostered. The principles of Government aid which have been set down should, it is considered, only apply to the development of water power (*a*) by a public utility company or (*b*) for the purpose of an industry in which Government has a particular interest or (*c*) for an industry which it is particularly desired to foster. A company developing power for its own factories, not coming under heads (*b*) or (*c*), would not usually require help.

The further question of indirect encouragement to power concerns by a guarantee to take the products of the industries using the power, on the analogy of that given to the Tata Iron and Steel Co., has also been suggested; but this is beyond the scope of the present report. Direct Government control of a power scheme, once established, beyond that required for the purposes of finance, is generally deprecated. Attention was called on more than one occasion to the fact that Government is apt to be unwilling to scrap antiquated plant, although by so doing ultimate economy would result. This criticism also applies to a considerable extent to British firms, especially as compared with American practice.

In Madras certain flourishing industries were started as demonstration plants by Government and then handed over to companies as " going concerns " ; the reverse of the ordinary plan that renders a privately started public utility undertaking liable to eventual purchase by Government or a local authority. Each plan has its good points. The suggestion that pioneer hydro-electric plants should be laid down by Government in favourable localities was mooted on several occasions. As a matter of fact most of the existing plants in India have been highly successful, and further demonstration seems hardly necessary except perhaps in localities far removed from the present installations. On the other hand, the risk of loss is small and the indirect gain in a well thought out scheme is certain. It comes to this then, that, whether by means of pioneer installations or by guarantees to private companies, direct Government aid is asked for practically everywhere except in the Western Ghats. The late Chief Engineer of this Survey was himself strongly in favour of *both* courses, and the present writer agrees with him. It may be mentioned here that the Hydro-Electric Power Commission of Ontario proposes to expend no less than £2,897,000 on 12 power stations at various places in the Province.

As regards Government assistance in the preliminary investigation, and even in the detailed survey of sites there is no difference of opinion. To what extent this is necessary or will be given remains to be settled by Government, but any help of this sort will certainly be welcomed. The cost of the preliminary investigation of a site that may prove worthless is very considerable. Again, as regards roads, railways and communications generally, the public naturally looks to Government for help. Before any site can be developed for power it is necessary to be able to convey plant and material there, and the cost of making a long mountain road might easily wreck a promising scheme.

The Water Power Resources Committee of the Board of Trade (a different body to the Committee of the Conjoint Board of Scientific Societies referred to elsewhere) in their Preliminary Report make the following remarks which, *mutatis mutandis*, are to a great extent applicable in India :

"From a broad review of the position, it is abundantly clear to the Committee that, in the development of the water power resources

of the United Kingdom, certain fundamental principles must be observed. For instance :—

(*a*) The whole of a watershed must be thoroughly studied and the fullest use made of its potential water power consistent with reasonable capital expenditure. A development which would only result in a part of the power being utilized should not be permitted if the ultimate use of the whole available power is thereby prejudiced.

(*b*) Proper regard must be shown to the interests of domestic and trade water supplies, fisheries, the drainage of adjacent lands, canals, and inland navigation, and in certain cases to local amenities.

Neglect to give consideration to some of these requirements has been responsible in the past for failure in the promotion of some water power schemes.

(*c*) A part of the available power must be reserved for use by the local population within the watershed, both for present requirements and also for prospective developments.

It is important to remember, however, that in the case of large water powers considerably in excess of local requirements, it would not, in general, be commercially practicable to ensure a cheap local supply of electricity unless the powers were developed to the maximum extent and the bulk of the output utilized by an industry requiring practically a continuous supply throughout the year.

There are two outstanding factors which have been prominent in arresting the wider development of water power schemes on a large scale in this country, namely :—

(*a*) The costly, protracted, and inefficient system of obtaining the necessary authority by means of a Private Bill.

(*b*) The multiplicity of interests to be reconciled.

With regard to the former [(*a*) above] the Committee is of opinion that if the rights necessary for the development of all water powers above a certain size were secured by the State, as and when required, many of the difficulties experienced in the past would disappear and preliminary waste of capital be obviated.

With regard to the question of multiplicity of interests, there is no doubt whatever that the powers now vested in numerous Departments, Boards and other bodies concerned with different aspects of the water problem require thorough revision and co-ordination. Many of the existing interests are, or may be, opponents of water power developments, and if proper use is to be made of the valuable national asset represented by the potential water power resources of the United Kingdom, the need of a simple, inexpensive and expeditious procedure for adjusting the claims of the several interests is vital."

20. *Charges for water power.*—The Government in India already has the control referred to in the extracts in the preceding paragraph, and various leases for the use of water power have at one time or another been granted. Some of these have lapsed, and in most instances there have been considerable discussions as to the rates which should be charged. In at least one instance a rate was initially suggested which would have been comparable to the total cost of fuel for working the undertaking by means of steam. Such a suggestion would be based on a false analogy with irrigation works, where the water is actually consumed, whereas for water power purposes it merely passes through the turbines unimpaired and can be used for any other purpose subsequently.* In fact it is gravity, not water, that is charged for since a given

* It may remove misunderstanding to point out that in the case of irrigation canals the charge made to the cultivator is based not only on the amount of water used, but primarily on the crops which are raised and on the acreage irrigated.

quantity of water will produce under 1,000 feet head one hundred times as much power as on a 10 foot canal fall. Any charge based on the horse-power developed or the number of units generated must therefore be illogical. It is suggested that as a general principle the charge for the momentary use of the water should be a nominal one, and that the revenue should be based on the principle of profit-sharing between the State and the promotor; a suggestion supported by the British Water Power Committee in their concluding remarks (p. 3 *supra*). Exceptions may however possibly arise in special circumstances. Thus, where power is generated from water running in canals constructed for irrigation purposes, not only is the power concern utilizing works already partly constructed but also it may happen that at times water is passed down when not required for the land. In the general interests of the community, which benefits by cheap power as well as by irrigation, it is doubtful if much more should be charged in this case, and it should in any case proceed from the profits of the undertaking and *not* from the sale of water. A much stronger case however is that of reservoir projects. There may be many instances where the cost of a new reservoir would only be justified for the combined purposes of power and irrigation; and in these circumstances the capital cost would naturally be proportioned between the two works. Similarly, if an existing reservoir is used for power purposes the promoters of the undertaking have the use of works, constructed at great cost, without which their project could not materialize. A somewhat higher charge would then be justifiable, even in the form of a charge for the water, since the utility of the reservoir for its prime function of irrigation might be affected.

In California a fee is paid on application for water and also every year afterwards. Mr. Barlow recorded his opinion that "The latter charge is unfair and tends to retard the development of water projects for the reason that it penalizes new projects, as old acquired rights pay nothing. *The interests of the State would be better served by the development due to the greater use of water than by the collection of small sums annually for the use of the water.*"

21. *Leases and agreements.*—Under existing regulations, the sanction of the Secretary of State is necessary for the granting of any concession—

(*a*) If the concession is intended to endure for more than 10 years and is not accompanied by an unconditional power of revocation or cancellation and imposes on the revenues of India an annual liability in excess of Rs. 50,000 ; or

(*b*) Imposes on such revenues, expenditure or liability to damages in excess of Rs. 12,00,000 ; or

(*c*) Involves the cession of property or rights estimated in value at more than Rs. 12,00,000 ;

and the sanction of the Indian Government is necessary—

(*i*) If the period in clause (*a*) exceeds five years and the liability Rs. 5,000 ;

(*ii*) If the sum in clauses (*b*) and (*c*) exceeds Rs. 100,000

Below these amounts the local Government can sanction the concession.

A certain number of actual or draft agreements for the use of water power have been collected, but the legal form which a lease should take cannot be considered in detail in this Preliminary Report, as it is highly complex and requires more information than is at present available. To delay publication for this would be a mistake, as the reconnaissance of new sites and the survey of known ones is at present far more essential than the consideration of the manner of their subsequent employment. Certain general principles have been laid down by the Government of India regarding the grant of concessions which involve monopolies of production and supply (Commerce and Trade. Resolution 1456-216 A of 10th April 1916).* Water power and electricity however do not appear to have been specifically considered in this connection, as the Resolution appeared rather to relate to

material things. Thus, while the claims of competing applicants must clearly be carefully weighed, a water power concession for a short period (" strictly limited period "is the phrase actually used) would be valueless. A period of 50 years would appear reasonable, as it is the period allowed to licensees under the Indian Electricity Act, and is long enough to attract capital. It is suggested that no charge should be made for a concession ordinarily, except perhaps a recovery of the cost of any survey work undertaken by Government beforehand. Where a decision has to be made between the claims of two or more applicants for a concession the claims of a public utility company should, it is considered, have precedence over an application from a purely industrial concern, partly because the latter can always obtain its power from a company, even though it may have to pay a slightly enhanced rate for it. Furthermore a company which is to serve the general public should be of greater value to the State than one which is serving its own interests only. Where the claims of two applicants who wish to float a public company have to be decided between, the concession will ordinarily be given to the one who obtains a license under the Indian Electricity Act from the Local Government concerned. The granting of this rests entirely with the Local Government, but it may be emphasized that it should be allotted to the applicant who is prepared to offer the best terms *to the general public,* rather than preferential terms to the Government. The latter invariably react on the private consumer. The same condition should, it is considered, also govern the grant of concessions for the use of water power. The claims of two competitors who both wish to develop water power for a purely industrial purpose should be settled, if possible, in the same way according to the conditions and rates under which they propose to sell their products to the public.

The conditions under which a concession for the use of water power should be granted to a public utility company should, it is considered, vary from those made for a company concerned with a particular industry. The works of the former can always in the last resort be taken over by a local authority or the Local Government under the provisions of the Indian Electricity Act, and can be continued in use and developed for the use of the public in the case of mismanagement or the insolvency of the concessionnaire. The deposit of a security, when once the works are in operation, does not therefore appear necessary in the case of a licensed company ; nor are any special provisions required for the removal of the works on the expiry or determination of the lease. In the case however of a concession for a purely industrial purpose, seeing that Government must be consulted as to how the site shall be developed, it appears necessary that the lease shall stipulate for the removal of any works that may interfere with the use of the power by other persons on the final expiry of the lease or in case of its determination for breach of the conditions imposed. Here it would seem desirable that Government should hold a substantial deposit to enable it to enforce the carrying out of any such orders, in case other applicants might be prepared to develop the site in a different way.

The dangers to be guarded against in giving a concession are:—

(*a*) The concessionnaire may merely hold his lease until he is bought out by a company. This is not in itself necessarily an evil, so long as power is retained to cancel the lease if work has not been begun and completed within a reasonable time. In order to prevent dog-in-the-manger inaction, a substantial deposit should probably be required, on which interest would be paid. This deposit should be liable to be forfeited if work is not put in hand and carried through within a reasonable time, especially if any other applicant is in the field.

(*b*) The site may be ruined by partial development. In the case of every public utility company it should be a condition that the initial works shall be so carried out that eventually the full possibilities of the site can be utilized if there is a demand for more power. If this condition would render the initial development too costly

for commercial success it would be for consideration whether Government should not come to the rescue with a share of the excess capital required. It must always be remembered that in such matters as storage works and canals or channels it is almost essential to build for the full ultimate requirements at the very start; but it is seldom possible to put plant down for the full power, so the extra capital is for the time being unproductive. In the case of an industrial development company this condition does not appear to be *necessarily* applicable; but foresight is required if good sites are not to be spoiled by partial development.

(*c*) Existing water rights and future irrigation demands must be safeguarded, or, in other words, no concession should be given until the irrigation possibilities have been fully considered. This, as a matter of course, is always done. The small riparian rights of private persons would seldom offer any difficulty as the whole extent of a hydro-electric scheme will generally only embrace a few miles of a channel. The utilization of the tail waters of the turbines is a more complicated matter. The most effective position for a power station might be such that a possible future canal supply would be jeopardized. In such cases the conflicting claims of power and irrigation should be threshed out by an authority interested, in both *i.e.*, by the Government itself rather than by a Department.

(*d*) Power should be taken in any lease granted to determine the same should the lessee stop using or not make sufficient use of the water power, provided that there are other applicants for its use.

The position as regards payments to Government by public utility companies may be summed up in two propositions.

First.—A company which is brought into existence for the good of the public is already doing a public service, and should not be burdened with special taxes on its construction or working which will inevitably be passed on to the consumer.

Secondly.—Such a public utility company should be given every facility to fight its early struggles, and only when it has achieved a position of prosperity should Government step in to share the profits; and then only with due regard to the consumer's prospects of a cheaper supply.

It is very desirable in the interests of British Trade that British Standards of pressure and frequency should be adopted in all future hydro-electric work, and the suggestion is put forward that this should be a condition of all leases and agreements for the development of water power.

The Standard Frequency of the British Engineering Standards Committee is 50 periods per second, with 25 periods as a secondary standard to meet special cases such as electric traction. For the latter work even lower frequencies have sometimes been used.

The Standard Pressures of the Committee are as follows:—

Standard low pressures (continuous and alternating).—

(*i*) at the generator, 115, 230, 460, 525V;

(*ii*) at consumer's terminals, 110, 220, 440, 500 V. Subsidiary standard in 3-phase circuits, 380 V between the principal conductors, giving 220 V between any one conductor and the neutral.

Standard high pressures (alternating) at generator terminals:—

(*iii*) 2,200, 3,300, 6,600, 11,000 V.

Standard primary pressures for alternating current transformers measured at primary terminals:—

(*iv*) 2,000, 3,000, 6,000, 10,000 V.

Standard secondary pressures for alternating current transformers measured at the secondary terminals :—

(*v*) 115, 230, 460, 525 V at no load.

(*vi*) *Standard continuous current pressure* for tramways, measured at motor, 500 V.

Although the Committee did not go beyond 11,000 V, pressures of 15,000, 30,000 volts and upwards are used for transmission of power.

CHAPTER VI.—THE WATER POWER RESOURCES OF INDIA.

22. *No estimate of the total power.*—To ascertain the total possibilities in the way of water power in India, even approximately, will take several years. To be of any value the estimate will have to be based on an examination of the detailed maps and the sites themselves, and of the rainfall records coupled with gaugings of the flow of the streams in each case. It might indeed be possible to obtain some idea of the total from an estimate of the areas of land at different elevations and the mean annual rainfall over those areas. The layered Atlas sheets of India give the former, and the rainfall maps give the latter, and assumptions as to the run-off, quite near enough for so rough an approximation, could be made. The British Water Power Committee in their Preliminary Report, working on these lines, have hazarded a guess that the upper reaches of the Irrawaddy and Chindwin Rivers might be worth a potential 7 million horse-power if a 500 foot fall could be obtained; no doubt a succession of falls amounting in the aggregate to 500 feet was in the Committee's mind, as it is doubtful if more than 50 feet could be developed at any one place on these rivers even by prodigal expenditure on dams and diversions.

Such estimates are however of no practical use in a country subject to a monsoon (or two monsoons) with a long dry season intervening. During the rains, except in the few places where the whole rainfall of a small catchment area can be stored at a high elevation, the vast volume of water flowing down to the great rivers must mostly remain unused. For example, there is an area in the Khasia and Jaintia hills, already referred to, of some 1,200 or more square miles area, with a rainfall varying from a mean of 410 inches over about 100 sq. m. in the middle to 100 inches at the edge; the general elevation is about 4,000 feet above the plains, and the drop is fairly steep on all sides and precipitous near the focus of heavy precipitation. The potential power of this small area is (on these lines) of the order of 4 million electric horse-power as the run-off is known to be extremely high. In the first place however a 4,000 foot drop could not be obtained, nor even half of it, except possibly by a succession of separate developments; secondly the incidence of the huge rainfall is such that, even with favourable reservoir sites, it could not for the most part be impounded; thirdly these sites do not even exist. The example is mentioned to show the fallacies underlying any such estimate.

23. *Water power at present developed.*—Table 2 shows the principle details germane to this Report of the water powers already developed for electrical purposes in India and the adjacent countries, except for a few small plants of which no particulars are available. These embrace high, medium and low falls; works dependant entirely or partly on main storage lakes, or with merely supplementary regulating storage, or with none at all; with and without open channels or special canals; with pipe lines or without pipes in the case of canals. The total plant installed (which includes spare plant) amounts to 111,860 electric horse power (83,000 k.W.) and the cost of installation (as far as it has been ascertained) of the hydraulic works, pipe lines, power house, plant and switchgear up to the outgoing transmission lines (which are excluded) varies as shown in Table 3. The sterling values are calculated at an exchange of 1*s.* 4*d.* to the rupee, at which it stood when all except Darjeeling (1*s.* 2*d.*) were put up. It stands at 1*s.* 8*d.* to-day and may rise further.

[TABLE 2

Table 2.—Existing hydro-

	Bengal.	Bombay.			Burma.		Kashmir.	
Undertaking	Darjeeling Munici-pality.	Bhatghar Dam.	Gokak Water Power Co.	Tata H. E. P. S. Co., Ltd.	Burma Ruby Mines.	Kanbauk Wol-fram Mine.	Jammu Power Instal-lation.	Jhelum Power Instal-lation.
Location	3 miles from town.	3 miles from Bhor.	Gokak, W. Ghats.	Western Ghats.	Mogok	Near Tavoy.	Jammu, Tawi.	Mohora
Source of water	Hill streams, tributary of Run-geet.	Lake Whiting.	...	Monsoon rain, stored.	Jaynee and Jaybu streams.	Sin Yat Chaung.	Ranbir canal.	Rapids in Jhe-lum River.
Minimum perennial flow of source (cubic feet per second).	10	150	...	*Nil*	80	*Nil*	500	4,000
Storage: Main (Millions cubic feet).	*Nil*	5,312	.	9,884	*Nil*	82	*Nil*	*Nil*
Storage: Regulating (Hours F. L. supply.)	10	...	...	1½	*Nil*	*Nil*	*Nil*	Small
Gross head (feet)	275 650	46 to 101	...	1,725	205	2,180	26	395
Length of open channel or canal (Miles).	2·9	...	.	4·6	*Nil*	*Nil*	*Nil*	6½
Capacity of special channel (Cusecs).	Small		...	480	..	...	...	560
Length of pipe line (feet)	720 1,450	...	...	13,000	2,250	15,320	*Nil*	750
Capacity of Plant: Installed (e. h. p.)	600	300	2,100	67,000	560	500	910	5,360
Capacity of Plant: For full development (e. h. p.)	600	3,000	...	67,000	560	750	1,340	20,000
Cost of hydraulic development, power house and plant, excluding transmission and beyond. (Rs. per K.W. *not* e. h. p.)	420	..	...	400	495	1,560	317	565
Remarks	Two plants in series, hydrauli-cally, up-per tail race led to lower reservoir. See plan and Plate.	Further storage contem-plated with a new dam; 24,000 m. c. ft.	...	See plan and plate.	...	...	...	..

lectric plants in India.

Madras	Mysore.	North-West Frontier Province.	Patiala.	Punjab.			Travancore.	United Provinces	
Government Cordite Factory.	Cauvery Power Scheme.	Malakhand canal.	Patiala H. E. Scheme.	Amritsar H. E. Works.	New Egerton Woollen Mills.	Simla Municipality.	Pulivassal H. E. Scheme.	Ganges Head-works Supply.	Mussoorie-Dehra Scheme.
Kaiteri, Nilgiris.	Sivasamudram.	Malakand	Nidampur	Near Amritsar.	Dhariwal	Chaba on Sutlej River.	Munnar.	Bahadurabad.	3 miles from town.
Two Hill Streams.	Cauvery Falls.	Canal diversion.	Ghagar Branch, Sirhind canal.	Fall in Bari Doab canal.	Upper Bari Doab canal.	Nauti Khad stream.	...	Two falls in Ganges canal.	Hill streams.
3	100 without storage; 890 at present.	...	550	1,050 for 240 days.	200	19	...	3,000	8¼
Two lakes 9 and 12.	500	...	*Nil*	*Nil*	*Nil*	*Nil*	...	*Nil*	*Nil*
Nil	*Nil*	...	*Nil*	*Nil*	*Nil*	4	...	*Nil*	½
650	410 to 426	...	8	6 to 9·7	11	540	400	19	1,000
Nil	17,000	...	0·2	Short diversion.	*Nil*	2¼	...	Short diversion.	*Nil*
Nil	1,000	...	550	2,300	...	32	...	600	...
2,130	950 to 1,100	...	*Nil*	*Nil*	*Nil*	1,300	...	*Nil*	4,850
1,350	22,650	330	285	270	900	1,680	530	600	2,400
1,350	32,000	...	430	700	...	2,000	...	3,000	2,400
368	550	630	900	630	..	710	...	300	240
Upper and lower lakes connected by pipe 1,580 ft. long. Capacity of lower lake	Krishnarajasagara Reservoir now partly available for power.	See Table 2 also.	Reserve steam plant; full supply for 260 days a year.	Used for subsoil pumping for irrigation.	Water insufficient often; stand by plant installed.	Extensions in progress. See plan and plate.	.	...	...

Table 3.—Limits of cost of existing hydro-electric plants in India.

	Per e.h.p. installed.		Per k.W. installed.	
	Rs.	£ @ 1s. 4d.	Rs.	£ @ 1s. 4d.
Maximum	1,170	78	1,560	104
Minimum	179	12	240	16
Mean of installations	674	45	900	60
True mean, i.e., total outlay divided by power installed (approximate).	350	23.3	468	31·3

Taking Indian exchange at the normal pre-war figure of Rs. 15 to £1 sterling these figures may be compared with those quoted in the Introduction to this Report. The present exchange position is favourable for the import of plant from the United Kingdom, but is more than balanced by the high level of prices there; so far as expenditure in India is concerned there has also been a great rise in the cost of materials since 1914 while labour shows an upward tendency.

24. *Sites for water power in process of development.*—The only hydro-electric schemes on which actual construction work is going on are that of the Andhra Valley Power Supply Co., Ld., Messrs. Burn and Co.'s Lagyap project in Sikkim, and that of the Burma Mines, Ld., at the Mansau Falls, Upper Shan States. Particulars of these are given in Table 4

Table 4.—Hydro-electric plants under construction in India.

Undertaking.		Andhra Valley Power Supply Co	Sikkim, Burn and Co's project	Burma Mines Ld.
Location . .		Western Ghats	Lagyap-la, East of Gangtok.	Northern Shan States.
Source of water .		Monsoon rain stored in lakes.	Lake fed by snows.	Mansan Falls.
Minimum perennial flow .	c. ft per sec.	*Nil*	No details received.	134
Storage, main . .	Millions c. ft .	12,000		*Nil*
„ regulating .	Hours full load supply.	—		*Nil*
Gross head . .	Feet . .	1,743		270
Length of open channel or canal	Miles	*None*		½
Capacity of same . .	Cusecs . .	—		254
Length of pipe line .	Feet . .	4,700		996
Plant being installed .	e. h. p. . .	68,000		9,750
Ultimate capacity of site .	„ . .	90,000		13,400
Total cost of hydraulic development, power house and plant up to terminals of transmission line per electric horse power.	..	—		Rs 260 at 1s. 4*d*.

25. *Sites for water power examined but not so far developed.*—Table 5 contains a list of known sites for hydro-electric works which have been examined or investigated (in greater or less detail) but have not so far materialized. It is quite possible that there may be omissions in the table, as it does not by any means follow that firms or prospectors discovering likely spots will publish their results to the world; on the contrary, they will be more likely to say nothing about them. This was the case with a perennial waterfall near Heho (q.v.), beyond Kalaw, in Burma, where it was subsequently ascertained that a Mr. Alexander had reported on the site as good for 2,000 horse power. Neither the report in question nor the engineer who made it has so far been traced. Too much faith must not be placed in the records of this table as it is certain that large assumptions have in some cases been made on the strength of insufficient data, *e.g.*, reservoir sites not geologically reported on, or discharges based on one set of observations taken perhaps long before the driest period or in a year following a wet year. Nevertheless, as the possibilities of a site are perhaps as often under-as over-estimated the total power is probably not far wrong. Further investigation of the more promising sites, especially as to the discharges and storage possibilities, is essential.

Table 5.—Sites examined but not developed.

Location of Project	Investigated or examined by	Source of water	Minimum per ennial flow	STORAGE SITES AVAILABLE: MAIN	STORAGE SITES AVAILABLE: REGULATING	Gross head	Value for continuous power	REMARKS
			Cusecs	Million cubic feet.	Hours F L supply or cubic feet	Feet	e h p	
Assam								
Damchara . .	Assam Bengal Railway.	Jatinga River .	?	3,000	...	200	7,000	
Near Dibrugarh .	Not known . .			.	...	.	26,000	
Shillong . . .	P W D. . .	Um Kia, Um Shupi	4	0 6	.	590	200	
Baluchistan								
Fort Sandeman .	Captain Duling	Sibaza Nullah . .	8	*Nil*	2 to 4	110	70	
Bengal								
Darjeeling I .	G P Robertson	Punagsa Jhora and Little Rungeet	25	..	Small	510	1,200	
„ II . .	A Stonebridge	Ruman and Little Rungeet River	..		„	...	2,200	
„ III	„ .	Kahil and Little Rungeet River		.	„ .	.	1,400	
„ IV .	„	Lodhoma River .	.	.	„ .	..	4,600	
„ V .	„	Balason River .		...			2,200	
„ VI . .	„ .	Teesta River .	10,000	*Nil*	*Nil*		26,000	
Kumani, Duars .	J W Meares	Jaldaka River	140	.	?	±1,000	Minimum 13,000 but in tea season far more	
Bihar and Orissa								
Mayurbhanj .	C H Douglas and P W D.	Burabalong River	?	2,200	400 m c ft.	950	10,000	
Bombay								
Koyna Valley Project .	Messrs Tata and A T Arnall.	Storage in Western Ghats	Small	120,000	...	1,600	300,000	
Nila Mula Project	Messrs Tata and H P Gibbs	Storage in Western Ghats	„ .	15,000		1,700	75,000	About to be developed.
Poona . . .	Mr Visvesvaraya .	Nira Canal . .	315	*Nil.*	*Nil*	84	2,300	
Burma								
Heho (Taunggyi) .	Mr Alexander, and Messrs Barlow and Meares	Heho River . .	60	Very large, but on agricultural land.	..	670	4,000 to 10,000	According storage
Cochin.								
Cochin . . .	Mr. G S Forbes .	Chalkudi River .	50	1,000	..	577	25,000	
Central Provinces.								
Balaghat . . .	...	Nahara River . .	?	Large .	?	500	9,000 ?	
„ . . .	..	Ukal River . .	...	„ .	?	1,000	4,000 ?	
[illegible] . .	... .	Indrawati River .	700 ?	?	?	80	5,000 ?	
[illegible]	Mr. [illegible]	[illegible]	[illegible]	Large	?	800	Large if feasible.	[illegible]

Table 5.—Sites examined but not developed—*concld.*

Location or Project	Investigated or examined by	Source of water	Minimum perennial flow	STORAGE SITES AVAILABLE — Main	STORAGE SITES AVAILABLE — Regulating	Gross head	Value for continuous power.	REMARKS.
			Cusecs	Million cubic feet	Hours F L supply or cubic feet	Feet	e h p	
Kashmir								
ashmir, Riasi .	Kashmir Durbar	Chenab . . .	...	..			30,000	
Madras.								
ogenkal Falls .	P. W. D. .	Cauvery River .	550	Large	..	46 to 85	2,500 to 3,500	
undah R. Scheme	" and H. P. Gibbs	Kundah " .	20	1,600	Fair .	3,000	20,000	Very promising.
ekadatu rapids .	G. S. Forbes .	Cauvery " .	550	...		175	8,500	
otacamund . .	H. P. Gibbs . .	Shola water fall, Sandy nulla.	1	0.5	..	1,000	100	
" . .	" . .	Pykara River . .	10	Site, but no details.	..	900 to 3,000	1,000	Involves tunnel through watershed.
ariyar Lake . .	A. H. Garratt and P. W. D.	Periyar Lake .	...	Vast	...	1,000	54,000	Negotiations proceeding.
unnymede (Nilgiri Hills).	J. W. Meares .	Coonoor and Katteri Rivers.	12	60 (or more)	65,000	1,020 (or more)	2,500 (or more)	Est. cost about Rs. 340 per e. h. p. (or Rs. 450 per kw.)
iruvani Project	P. W. D. and R. H. Martin	Siruvani River, Nilgiris	45	280 to 450		1,200	5,000	Site for dam reported unfavourable.
N.-W. Frontier Province.								
alakhand Tunnel .	Capt. (now Lt.-Col.) Battye, R. E.	Upper Swat River Canal.	1,000	..	..	230	20,000 or more.	
Punjab.								
akra Dam . .	F. Milne . .	Sutlej River . .	2,700	Not to be utilized	..	330	81,000	
adhupore . .	Punjab Power Association and F. Milne.	Upper Bari Doab Canal.	1,300	*Nil.*	...	140 to 200	16,000 or more.	
asul . . .	Capt. (now Lt.-Col.) Battye, R. E.	Lower Jhelum Canal	4,500	*Nil.*	*Nil.*	80	33,000	
mla . . .	F. Milne . . .	Nauti Khad extension	8	20	...	1,600	6,700	Pipe line 5,000 feet.
United Provinces.								
ekhwar Bridge, [illegible]	U. P. Power Associa-[illegible]	Jumna River . .	1,000	...	?	130 or	12,000	

26. *Possible sites for water power requiring reconnaissance.*—Reference has been made above to the inquiry made for possible power sites in 1905, at which time it is clear from the returns sent in that the conditions that make a "good site" were very little understood, even by engineers of the Public Works Department. The enquiry was begun afresh under Mr. Barlow's direction in November 1918 and was continued up to the date when this Report went to the Press. In every part of India and Burma sites new and old were discussed and an endeavour was made to obtain information on salient points. The results of this preliminary enquiry cannot well be put in tabular form, as there would be too many blanks to the prizes. It will be preferable merely to give such information as has been collected in the form of notes on rivers, arranged by Provinces and, in each Province, in alphabetical order as far as may be. The sites given in Table 4 are mostly repeated, as further information is desirable although more may even now be known than could be put in a tabular statement. The fact that more possible sites are listed in Burma than elsewhere is due to the fact, explained above, that during the first season's tour that Province received more enquiry and attention than all the others combined; the Central Provinces is a good second, but many of the sites there are sure to prove useless. *It must be emphasized that all sites of which practically nothing is known, as well as all which have previously been recorded, are entered in the lists. Until they have been examined it is impossible to say which are worthless and which are worth further survey.* By making the list as complete as possible the worthless ones can, it is hoped, be eliminated once for all after the next season's work.

A mere list of sites makes dull reading, and the matter collected has therefore been relegated to Appendixes 5 to 14. Here some general notes on the conditions in each Province will be given, in alphabetical order.

Assam.—The whole area of the Khasia and Jaintia hills offers great possibilities; other hill districts such as the Garo hills are less civilised and are little known or mapped, but may have favourable sites for eventual development. The road to Shillong runs through dense jungle where the hills and valleys rise and fall very rapidly. Reservoir sites in the lower parts seem unlikely; the slopes of the rivers and their discharges appear too small for any considerable developments of power. Detailed reconnaissance may however disclose reservoir sites; but the jungle is almost impenetrable, except for an elephant. The upper parts can be prospected on foot and appear more hopeful, *e.g.*, the Umian River near Barapani, but there is little information available. The proposed Pandu-Shillong railway can probably be supplied with power for working when sites have been further examined. Discharges are being taken where possible, *e.g.*, on the Um Rai River, near the road. A site near Saitwait village, on Kersh's (?) old road trace, 15 miles below Lynkerdem on the Thanjinath Plateau was also mentioned as worth examination for the Pandu Railway. This has not yet been identified on the map.

The upper plateau between Shillong and Cherrapungi is a rocky country intersected by numerous deep nalas, and narrow valleys, the tributaries of the Shella River (q. v.,) carrying off the drainage, with very quick slopes; no storage of large amount appears possible without dams of great height, while earthquakes render these unsuitable, except possibly in reinforced concrete. This is the region where the rainfall averages 400 inches over a strip of country about 15 by 10 miles. Transport from the plains below Cherra would be difficult as it is all flooded in the rains, though country boats come to the foot of the hills. There is good limestone and coal of good calorific value but bad storing quality. The road towards Laitkynsew may offer reservoir sites. Near Cherra the two best reservoir sites appeared to be on the tributary of the Um Long which runs near the road at mile 30 and on the Um Pynjngithulli near Umsohphi Village. The former is moderately flat, with rice fields and a few huts, on the west side of the main nala; and there is a local pocket which may be suitable for a reservoir. In the same tributary lower down and a little above the falls shown on the map there is another possible site. As regards the Pynjngithulli there is one place much better than elsewhere about half way up the nala above the falls, where the valley is wider and has a less rapid slope. Modern 1 inch contoured maps [illegible]

close further possible reservoir sites; but time has not allowed this to be done as yet. There are scores of waterfalls marked on the map, but they are mostly dry the day after rain has ceased to fall. December and January are ordinarily the only really dry months; November and February average about 2 or 3 inches.

The names of streams are often different on the Atlas and detailed sheets, and the alternatives are given.

A list of possible streams and sites for reconnaissance will be found in Appendix V.

Bengal and neighbouring States.—Bengal proper is almost entirely flat and offers practically no chance of water power; and the proximity of the coal fields would in any case militate against the financial success of such undertakings. At various times in the past proposals have been made for supplying power to the great industries on the banks of the Hooghly; either by transmission of power from large stations in the Raniganj coal fields, 100 miles off, or again from the Burabalong River in Mayurbhanj State, Orissa, (q. v.) an even greater distance. The Hooghly River Power Co. was formed for the first of these projects, and a license was granted, but it fell through. The cities of Calcutta and Howrah obtain their supply from the Calcutta Electric Supply Corporation (see Table 2) but hitherto little progress has been made towards supplying the local mills from the power house at Cossipore. The fact no doubt is that, with modern steam engines and boilers, most large factories can obtain their power cheaper by having their own plant; where the plant is old or out of date it may be preferable to purchase power rather than to lay down capital for a new drive, especially as hitherto the cost of purchased power has steadily declined.

In the coal fields area also there have at various times been proposals for central generating stations at the pit's mouth, for use in the collieries. A beginning has now been made in this direction, but the tendency to instal rival plants is strong and cannot make for economy. Recently a considerable part of the "Bengal" coal fields has been transferred to the new Province of Bihar and Orissa.

There are endless possibilities of water power in the Himalayan regions bordering on Bengal in the North, for the most part in Sikkim and Bhutan. Here the rainfall is very heavy, 100 inches and upwards, and the larger rivers are also snow fed. They are however subject to great floods and no reservoir sites seem likely, so that the cost of development will generally be high. A list of sites, some of which may, when further details are obtained, prove worth detailed examination, will be found in Appendix VI.

Bihar and Orissa and neighbouring States.—The possibilities of water power, especially from storage, appear to be considerable in this Province, though as yet there has been little time to investigate sites or determine run-offs and discharges. The region around the coal fields is likely to obtain all the power it requires from that source, and in the absence of "White Coal" there is a paucity of perennial streams. The Palamau and Hazaribagh hills; the Ranchi District; the Mayurbhanj State; and the intervening uplands have produced many suggested sites for reconnaissance as will be seen by the list. A skeleton map of the Province has been prepared in the Chief Engineer's office, showing the sites and other data. Mr. Clayton has found time to visit many of the sites and to take discharges and determine other data, both positive and negative. A list of sites in Bihar and Orissa will be found in Appendix VII.

Bombay.—There are probably endless sites in the Western Ghats, of which the best have already been examined by Messrs. Tata's engineers. The rainfall is heavy, especially at the scarp of the Ghats, where it locally reaches 200 and even 250 inches; but nearly all concentrated between June and September. Storage is therefore an essential of practically every project in this area; the levels are *prima facie* favourable; the fall is generally of the order of 1,000 to 1,800 feet, obtained for the most part by piercing the watershed; the demand for power is large; and the tail water could sometimes be used further on for irrigation. Dharwar, Satara, Poona, Belgaon, parts of Nasik and Ahmednagar and probably the Panch Mahals and Khandesh were the districts specially brought to notice. The Nerbudda and Tapti rivers flow

through the Panch Mahals and sites can probably be located. This is a large cotton growing area. The cost of existing reservoirs in the province varies from Rs. 212 (Gokak) to Rs. 570 (Chankapur) per million cubic feet. Sind is unlikely to have any power.

An excellent layered map showing the sites of existing and projected irrigation and power works has been prepared under the orders of the Chief Engineer, Public Works Department, on a scale of 8 inches to the mile. A list of sites will be found in Appendix VIII.

Burma, with the Shan States and neighbouring territories.—The whole of this Province especially the Shan States, is well furnished with great possibilities of water power except in the comparatively small dry zone. The great rivers for the most part rise very slowly in elevation, but their numerous tributaries, and the feeder streams of these, rise in the hills and often present good falls. There is also more perennial water than is generally found in the peninsula, though there is no "White coal" except in the upper catchments of the Irrawaddy and the Salween. Generally speaking there appears little prospect of reservoir storage, as the limestone which forms so large a proportion of the hills is much fissured. "Natural bridges" where a river disappears completely underground are a common feature of the country; and the reappearance of the stream at large springs elsewhere is consequently also common. The mineral resources of the Province are being developed but have not been fully prospected, for large areas are almost unknown and are unsurveyed. Sooner or later however there should be a considerable demand for power, and it is possible that some of the promising sites may prove worth development for special industries to be established near them. The minimum discharges are in very few cases known, as for the most part no measurements have been made until undertaken for this survey. The rainfall generally over the Province will be seen from the rainfall contours on the map in this report, and some figures are given with each entry in the list of sites. Generally speaking nearly the whole of the rainfall is precipitated in 6, 7 or at most 8 consecutive months of the year; to the extent of about 96 per cent. of the mean annual fall. It follows therefore that, in the absence of large springs, the discharges must fall very low towards the end of the dry period. Unless therefore reservoir sites prove practicable, as to which there is very little information at present, the smaller rivers may not prove of much value.

A map of the Province has been prepared in the Chief Engineer's Office, giving all available information as to roads, railways, irrigation stations, power stations, altitudes and rainfall. A list of rivers and sites requiring reconnaissance will be found in Appendix IX.

Central Provinces and Berar with neighbouring States.—There are few perennial rivers except the Indrawati, Nerbudda and Tapti, so storage will generally be necessary. Sites for reservoirs exist plentifully, but will not be cheap to develop; indeed the relative cost is stated often to rise as the reservoir capacity is increased. It averages Rs. 289 per million cubic feet of water. Owing to the uncertainty of the rains considerable carry-over capacity will in every case be required. The plateaux of the Central Provinces however undoubtedly offer possibilities which are well worth examination; they are generally from 500 to 2,000 feet or more above the surrounding plains, and catch the rainfall. The Satpura plateau, the Vindhyan escarpment with the Malwa plateau, and the hills of the Bastar State embrace the main elevated regions. It is strongly held in the Province that for any large project the combination of irrigation from the reservoirs should be combined with power, and that this combination may be financially successful when neither might be so alone. The local work of the survey (other than topographical) should therefore be undertaken by an officer of the Central Provinces Irrigation Department. Officers of the local administration in the Central Provinces, despite shortage of staff and notice, went to great trouble in preparing an excellent layered 8 inch map of the Province with possible sites marked, together with memoranda on various proposed power sites. In the list of sites given below there are certainly many that are absolutely useless for power purposes, but until they have been examined it is impossible to determine which are in this category; the information is far too sketchy. Some of the reservoir sites for instance are below any likely fall, but may nevertheless prove useful

for irrigation purposes in combination with other tanks higher up the catchment areas.

The average monsoon rainfall of the Province varies between 35 and 60 inches, but is very liable to fall short in particular years. Furthermore it falls almost entirely in 4 months, June to September. There is generally an inch or two in October, and coming after the heavy rains this will give a good run-off and perhaps obviate drawing on the storage. The other months seldom have as much as half an inch.

The memoranda of the Director of Industries, the Under Secretary, Public Works Department, and the Executive Engineer, Waingunga Division, may be specially mentioned. The following list of catchment areas of rivers where the 2,000 foot contour cuts them will be found valuable. It was prepared locally for this investigation.

Table 6.—Catchment areas of rivers in the Central Provinces where the 2,000 feet contour cuts them.

Name of District.	Contour.	Name of stream or river.	Catchment area in square miles	REMARKS
Betul	2,000	Taptee	228·00	
Do.	2,000	Wardha	84·70	
Do.	2,000	Khursi	37·50	
Do.	2,000	Purna	93·00	
Do.	2,000	Machna	136·00	
Balaghat	2,000	Deo	91·00	
Seoni	2,000	Wainganga	275·00	
Do.	2,000	Tel River (Tributary of Wainganga).	178·2	
Jubbulpore	2,000	Mahanadi	46·27	
Mandla	2,000	Nagiar (Tributary of Mahanadi).	34·19	
Do.	2,000	Nerbudda	1,205·88	
Do.	2,000	Kashmeri (Tributary of Halon River).	275·2	
Do.	2,000	Burmer or Burhner	605·6	
Chhindwara	2,000	Kanhan	178·14	
Do.	2,000	Bel	356·39	
Do	2,000	Sitarewa	94·45	
Do.	2,000	Pench	527·62	
Do.	2,000	Harod	146·47	
Do	2,000	Umra	51·87	
Do	2,000	Kulbehera (Tributary of Umra River).	221·92	
Amraoti	2,000	Khandu	33·25	
Do	2,000	Khursi	38·79	
Bastar State	2,000	Indrawati River	192·00	

A list of sites in the Central Provinces, requiring reconnaissance, will be found in Appendix X.

Madras and neighbouring States.—The hill ranges of Madras offer many possibilities, as yet little examined. In some parts there are two monsoons, and a far more even distribution of rainfall than elsewhere. Madras is also famous for its reservoirs and irrigation tanks, so it is probable that many similar sites may hereafter be found suitable for storage for power. The cost of reservoirs varies from Rs. 134 (Kistna) to Rs. 412 (Periyar) per million cubic feet. The whole Nilgiri area requires special attention, as many sites are known to exist but require investigation of discharges, run-off, reservoir sites and practicable falls. Other hill ranges, less known at present, may prove as good.

A list of sites brought to notice for reconnaissance will be found in Appendix XI.

North-West Frontier Province and neighbouring States.—This district is in the dry zone, with a rainfall averaging 10 to 15 inches but often less. The Swat and Indus rivers, the Kunar (a tributary of the Kabul river from Chitral) and the Kunhar (a tributary of the Jhelum) are all snow fed and therefore have a large perennial flow and great aggregate fall. Other rivers such as the Gumal, Tochi, and Kurram have very large catchment areas over the border in Baluchistan and Afghanistan. Owing however to their position on the frontier and the wild nature of the country, both in its physical and moral aspects, very little prospecting work has been done; indeed it is very unlikely that power sites, however good, could be utilized. Industries of any magnitude, beyond agriculture, are unlikely.

A list of sites brought to notice will be found in Appendix XII.

The Punjab and neighbouring States.—The five great rivers of the Punjab, namely the Sutlej, Beas, Ravi, Chenab and Jhelum, all take their rise among the Himalayan snows, outside British India, descending to the plains in a series of rapids. With the exception of the Beas, which will no doubt be utilized eventually, they are all harnessed for the service of the vast canal system which spreads over the arid plains of the province. There is also much local and indigenous irrigation on the terraces in the hills, which taxes the tributaries considerably; and nearly every little channel of this nature has its primitive water wheel for grinding the village corn. These water rights are jealously guarded. The irrigation interest is therefore paramount, but there is very little likelihood that any water power scheme (other than a canal fall development) could interfere with the canal system, which takes its rise exclusively in the lower reaches. That this is true of the Sutlej is explained below. The potential power of these rivers and their tributaries, even on their dry weather discharges, is vast and need not be calculated; but hitherto they have been little examined for practicable sites for water power where the development would be reasonable in cost. A few miles of the rapids of the Jhelum at Mohora have been developed by the Kashmir Darbar (see Table 2) and this will serve as an index of the power contained in the Himalayan reaches of the five rivers. Hitherto the demand for electricity has been mainly confined to the towns and cantonments of the province, which have either installed small steam or oil plants or have had to forego the benefits of the electric fan throughout the sweltering heat of the summer. The industries that exist are scattered, and there are no great centres where power on such a large scale has been demanded as would invite capital to embark on large projects. It may be hoped that progress may be on broader lines in the future, for all the power that can be demanded can be supplied over and over again from the "White Coal" over the border. The rainfall cannot always be given as even where known it varies greatly over the vast catchments of the large rivers. Generally speaking however the monsoon breaks at the end of June and lasts till September only. A certain amount of snow falls during the winter in the hills, and local thunderstorms, sometimes severe, also occur at any time.

There are many falls on the various canal systems, some of which are capable of giving considerable power for the greater part of the year; all however suffer from the disadvantage of a periodical closure. As regards this source of power it is clear that the Irrigation Department must have the final word as to what may or may not be done. As regards new projects, however, mention has already been made in para. 5 of the fact that two or more small falls have often been constructed where a single fall of greater drop would have been practicable. A little extra expenditure to begin with may make a bad power site into a good one; and it is to irrigation requirements, such as sub-soil pumping or high level pumping, that such power schemes will probably look for their outlet.

The late Mr. Barlow recorded the following note on the subject, in view of the difference in the practice of his own Province (the United Provinces) and the Punjab.

"The Punjab Canals run in rotation, *i.e.*, different branches in different weeks, and the main canals have sometimes to be closed for a month in the monsoon or in winter on account of heavy rain or for silt clearances. There are falls in many places of 8 to 15 feet with good discharges and these

might be used for pumping water for irrigation and by this means reduce waterlogging and also enable certain channels to be closed and the water used elsewhere. The Irrigation Department think that the water rate would have to be raised to enable these schemes to be a paying proposition, but consider that the cultivators will be able to pay it. There are also many local industries on a small scale which would probably come in if this power were provided." A map has been prepared in the Chief Engineer's Office, Irrigation Branch, showing the canal systems and other relevant data.

A list of sites—probably less complete than any other—will be found in Appendix XIII.

United Provinces and neighbouring States.—There are great power possibilities in the United Provinces, especially in the Himalayan and the Bundelkhand and Baghelkhand areas. The rivers from the hills are largely utilized for irrigation, and reservoirs of large size are common; it may therefore be supposed that many unutilized sites for reservoirs are to be found, capable of being used for power purposes before feeding the rivers and canals below. The cost of reservoirs varies from Rs. 149 (Gaggar) to Rs. 418 (Betwa) per million cubic feet. This preliminary enquiry supports the supposition. A table has been locally prepared showing the catchment area, storage capacity, probable maximum flood and cost of many existing or under construction storage works in Bundelkhand; it is not printed here, but is on record. The cost per million cubic feet of useful storage varies however as follows :

Seven cases, between Rs. 800 and Rs. 1,400, all small by comparison, *i.e.* 100 to 600 m.c. ft. useful storage.

Seven between Rs. 192 (minimum) and Rs. 400, varying from 343 to 11,250 m.c. ft.

Ten between Rs. 400 and Rs. 800, of all capacities.

There are many small falls (up to 12 and 14 feet in a few cases) on the irrigation canals. The majority of these are of small account for power purposes and suffer from an annual closure; but a few offer good power and others may perhaps be utilized hereafter for high-level or subsoil irrigation pumping. The complete list of falls over 3 feet is therefore given so far as data have been supplied.

An excellent map of the Province, marking power and irrigation sites, has been prepared under the orders of the Chief Engineer, Public Works Department.

A list of sites brought to notice, with canals at the end, will be found in Appendix XIV.

27. *Native States and territories adjoining British India.*—As explained in the note at the beginning of this Report, the term "India" is used in its geographical atlas sense. Water power refuses to be confined by territorial or political boundaries or by sectional or Provincial interests; it exists where Nature places it, although it may be artificially controlled to some extent. A promising scheme may take its rise in one State, be developed in a second and utilized in two or more others; it may be necessary to modify it so as to meet existing water rights or future irrigation requirements, but here the advantages need to be properly balanced by independent authority. It so happens that a considerable amount of the available water power of India takes its rise outside British territory, and in some cases power sites will eventually be found (where this is not already so) either on a river which is also a political boundary or entirely over that boundary. Certain instances are already given in this Report, and if any places are incorrectly located the Compiler apologizes for the errors. Hitherto the two officers deputed to carry out the Hydro-Electric Survey have been unable to visit a tithe of the sites referred to, and the first reconnaissance of all will certainly tax the energies of a considerable staff for several seasons, while actual survey work is proceeding at sites already favourably reported on. The material in this volume will however show what is required, and much information can be collected in advance by the engineers of the various States which may wish to have their water powers examined. Requests, formal or informal, have been received asking the Chief Engineer, Hydro-Electric Surveys, to visit or report on water power in general or sites

in particular in the following territories, which are arranged alphabetically :—

ALWAR.—The Sewai Maharajah enquired of the late Mr. Barlow regarding the bund at Bara.

BARODA.—The Hon'ble the Resident at Baroda refers to the Orsang, Oonch and Heran River projects; the Saharmati reservoir projects at Hadol and Dharoi; Khadiar Nala falls in Dhari (Kathiawar), and Mokhadi falls in the Nerbudda. He has been asked if data as to discharges, falls, etc., can be collected. In reply to his enquiry about a visit to Baroda State, he has been informed that inspections are not possible before the next cold weather.

BENARES.—The Karamnasa and Chandraprabha falls are referred to in Chapter 6 of the Report under the United Provinces. The Darbar has been asked that they may be reported on further. His Highness the Maharaja has made a request for a visit to examine the sites.

BHARATPUR.

BHOPAL.—The State Engineer refers to two alternative sites on the Betwa River which it is desired to have examined, and as to which details exist in his office. A visit to the sites next cold weather has been promised.

DHAR.—The Political Agent in the Southern States of Central India has also referred to the Dhari waterfalls on the Nerbudda, which have been reported on by Mr. Hartley. An endeavour will be made to visit the site next year if possible.

HILL TIPPERA.

HYDERABAD, DECCAN.—The Mint Master and Chief Electrical Engineer has enquired if the data of the rivers in His Highness the Nizam's dominions will be of value.

JAWHAR.

KAPURTHALA.—The Darbar intimates that the investigation is welcomed.

KASHMIR AND JAMMU.—The Chief Electrical Engineer refers to the 20,000 H. P. scheme on the Chenab and to the prospects of supplying power to the Punjab from Kashmir.

KOLHAPUR.

MANDI.—The Darbar asks for examination of the confluence Beas and Suketi Rivers at Mandi.

MYSORE.—The Hon'ble the Resident at Bangalore has asked to be informed if the Survey proposes to visit Mysore.

RAJPIPLA.

RAMPUR-BASHAHR.

SIKKIM.—The Political Officer in Sikkim has offered to make arrangements for a visit there in connection with the water powers of the Lagyap Pass and the Teesta (*q.v.* under Bengal and neighbourhood); also the Rungpo. There is evidently great power available all over Sikkim.

SUKET.—The Darbar welcomes the investigation and calls attention to the Suketi, Bhawana Khad, Samal Khad as well as minor streams.

TEHRI-GARWHAL.

28. *Summary of results.*—Taking into account tables 2, 4 and 5, and the sites in Appendixes V to XIV where there is a reasonable prospect of obtaining power to the extent estimated by the persons concerned, the round total comes to about 1,771,000 electrical horse-power actually in sight. The figures, classified both by provinces and by the degree of reliability of the estimate are given in Table 7. *The total is of course vastly below the actual available power which the final results of the survey will disclose.* Thus there are over 130 possible sites, to which attention has been drawn, of which nothing whatever is definitely known; there may be hundreds more yet to be found. Apart from this, however, the great perennial snow fed rivers have been scarcely touched upon; their potential power has not been determined and is in no way brought into the table, except as regards a few definite projects. These for the

most part only bring in a few miles of the river, and a few hundred feet of fall. The calculation of the British Water Power Committee relating to the Irrawaddy and Chindwin Rivers, with their 7 million potential horse power, has been referred to earlier; where it is also explained that as most of the discharge comes down in a few months the actual potential power available for 12 or even 9 months will be far less. Even so, many millions of horse power could certainly be obtained all the year round from the Himalayan mountains *if cost were no object and fuel no longer existed.* Thus the combined *minimum* discharges of the Indus, Jhelum, Chenab, Sutlej, Beas, Jumna and Ravi Rivers amount to over 36,000 cusecs where they enter the plains, equivalent to well over 3 million e. h.p. *per 1,000 feet of fall*; these rivers and the tributaries that feed them rise in mountains up to 20,000 feet or more in altitude, and are not above 1,500 feet above sea level where they enter the Punjab plains. Similar considerations apply to the Ganges, the Sarda, and the many rivers rising outside British India to the east up to the Brahmaputra, and again in Burma to the Irrawaddy and the Salween. What the total power on the minimum discharges may be is incalculable, while on the normal discharges throughout the greater part of most years it is certainly several times as great. (The table is on the following page).

29. *The Key Map of Sites.*—The general map of India on the scale of 64 miles to the inch, which will be found in the pocket, has been specially prepared for this Report by the Superintendent of Map Publication, Survey of India. It shows as far as possible on this scale the rivers, railways, and contours. The possible power sites marked on it do not pretend to be in exact position; they serve to indicate localities merely, as the exact squares where known are stated in the text. A certain amount of information is also given regarding the occurrence of coal, oil and minerals, but this again does not pretend to be complete or very exact. It by no means follows that areas without any entries have no water power; it merely means that no data have been collected so far. Of the hundreds of 4", 2" and 1" maps referred to in the Appendixes hardly any have been examined as yet, as early publication of the Report with a view to future work is more important than completeness.

[TABLE 7.

Table 7.— Probable water-power of India, so far as determined.

Figures are electrical horse power continuous, *not* 12 hour.

Name.	Developed ; See table 2	Under construction. See table 1.	Known sites See table 5	Probable sites from list of sites.	Canal falls not included in tables 2, 4, 5.	Total.	REMARKS.
Assam	*Nil*	..	33,200+	18,000	..	51,200	About 10 sites unexamined.
Bengal	600	.	50,600+	153,000	...	203,600	2 sites unexamined. The Tista has also vast power.
Bihar and Orissa	*Nil*	..	10,000	2,800	..	12,800	9 sites unexamined.
Bombay	40,000	45,000	189,800	68,500	.	343,300	9 sites unexamined.
Burma	1,060	13,400	10,000	429,000	...	455,000	Over 40 sites unexamined. The great rivers in the north have not been examined.
Central Provinces	*Nil*		20,000 ?	133,000	...	153,000	24 sites unexamined.
Cochin	...	...	25,000	..	...	25,000	...
Kashmir	28,300		30,000	...	...	58,300	The Himalayan rivers have great unexplored power here.
Madras	1,350	..	94,000	12,000	..	107,350	8 sites unexamined
Mysore	32,000	...	.	...	...	32,000	..
N.-W. Frontier Province	330	...	20,000	...	.	20,330	.
Patiala	285	...	...	...		285	...
Punjab	3,600	...	136,700	16,000 exclusive of the Indus, etc.	108,200	264,500	5 sites unexamined. Small canal falls good for less power during part of year. See also preceding page.
Sikkim	*Nil*	8,000	...	..	...	8,000	...
Travancore	530	...	...	...	...	530	...
United Provinces and Benares	5,400	...	12,000	8,300	11,900	37,600	28 suggested sites unexamined. Canal falls good for more power for 9 months. Vast power in Himalayan rivers, not explored.
Round Totals	115,000	66,400	631,300	840,600	120,100	1,774,000	...

CHAPTER VII—FUTURE WORK OF THE HYDRO-ELECTRIC SURVEY.

30. *Agency for carrying out the future work.*—It is not necessary or within the Compiler's province to lay down exactly how the work necessary to complete this report shall be carried out. In certain of the following paragraphs suggestions are made as regards specific points requiring attention. It is clearly essential that officers shall be placed on special duty, at least during the dry months and during the period when reconnaissance and survey work can be carried out. For this work officers with local knowledge will be required in each Province. In order that the work of the Survey may be of use to Indian industries and Empire Resources it appears essential that the Chief Engineer of the Survey should act as a liaison officer to co-ordinate the work that is being done and to see that it is done in the manner required, to prevent overlapping on boundary rivers, and to draw up progress reports as the work proceeds. In order to save delay and circumlocution he should, if possible, be allowed to correspond directly with all gazetted officers of the Forest Department and of both the Irrigation and Roads and Buildings Branches of the Public Works Department.

In provinces where reservoirs will generally be necessary it is clear that officers conversant with irrigation work must be largely employed; and wherever there is a prospect of combined works for irrigation and power, whether from rivers or reservoirs, the same remark applies. At the same time there may be in such districts other sites of a totally different character, the reconnaissance of which requires a knowledge primarily of water power and the best methods of developing it in each case. It is very desirable that arrangements shall be made at the earliest possible date for resuming field work, and officers should therefore be detailed for this in each Province as early as possible; see paragraph 34.

There is considerable danger that, in the absence of specific demands for power, the work will be shelved. The co-operation of the Water Power Committee of the Conjoint Board of Scientific Societies, which has been offered, may be invited to prevent this happening.

31. *Census of power.*—It is hoped that the somewhat sketchy summary of the power used in certain parts of India, given in paragraph 14 *supra*, will be an incentive to the completion of these tables on comprehensive lines, for which there has not yet been time. It is by no means easy either to collect or tabulate the results in such a way that they will be of practical use, as most power users do not know anything of horse-power. (See Appendix IV). It is however desirable that some approximation should be known as to the amount and nature of the power used over areas of reasonable size, such as districts or sub-divisions of districts. Reference to the permissible cost of hydro-electric schemes in paragraph 78 will show that it depends on their position with regard to power requirements, the cost of fuel at present used, and the "load factor," which term is there explained in non-technical language. The census of power should therefore give, for each area, the installed horse-power subdivided under water power, steam power, oil engines, gas engines (if there are any such); the average cost at site of the coal or oil used as fuel, and where it comes from; and (in very general terms) the purpose for which the power is used and the ordinary hours and days per annum of working. If a project is likely to materialize all these figures are essential in order that its prospects may be gauged. The first step in a detailed investigation is to draw up probable load curves of the completed scheme in order to see what

plant and transmission lines are required. It is suggested that the final tables shall be drawn up in the following manner :—

Province________________District________________Boundaries of district approximately, by sketch map or otherwise________________

	Water Power	Steam Power	Oil Power	Electric Power	Average Working period.		
	b. h. p.	b. h. p	b. h. p.	b. h. p	Days per year.	Hours per day.	
Pumping plant.							
Agricultural plant.							
Textile machinery in factories.							
Machinery in engineering works.							
Other factory plant.							
Isolated plants.							

Source and average cost per ton in district. Coal Rs.
Bulk oil Rs.

By water power, steam power, etc., is meant the direct driving of plant by turbines or engines, not through electricity. By electric power is meant both where the concern has its own plant or where it takes a supply from a power concern.

It is suggested that Directors of Industries, who have supplied the data already included in this Report, should be asked to collect the full data for the Census on these lines, and then to have them analysed and put into form by a mechanical or electrical engineer accustomed to the vagaries inherent in the returns as received. The papers already in hand can be returned for this purpose.

32. *Rainfall records and Map.*—(See Chapter 2). From the records of the Meteorological Department of the Government of India a small scale map, showing average annual rainfall contours, has been published. The Railway and Canal map of India, on the scale of 32 miles to the inch, is also contoured in the same way, with the help of such additional records as the Irrigation Department possesses. Unfortunately these records fail to cover in detail many areas which are out of the orbit of irrigation works and observers, and which nevertheless may prove of great importance to the hydro-electric survey. For here it is the detailed rainfall contours over a definite, and perhaps small, catchment area that are required, rather than the general lines of the continent. In some cases there may not be a single recording station within such a catchment. Where a sufficient number of observations exist the rainfall contours can be filled in from these by following approximately the geographical contours, as this is found to give the most probable results. They may however be very far from the actual truth over small areas. Thus, on the seaward edge of the Western Ghats, the existing maps show a series of contours, at closer intervals as they proceed, from 30 inches up to 100 inches at the edge ; and 150 inches on the seaward plains. It is however well known that in parts the annual fall amounts to 200 and even 250 inches. Any cliff exposed to the moisture laden monsoon currents is certain to arrest them and direct them upwards, and thus [illegible]

to cause very heavy local precipitation. The cliffs below Cherrapunji are an even better example than the Western Ghats, and there may well be other similar places of which no records exist at all.

There are however hundreds of places in India where rainfall records have been kept regularly for many years, and yet never used except by those who keep them. Thus every tea garden, every coffee or cinchona plantation, has its raingauge and book of records, and these will to a considerable extent be found in the hills that may prove to be likely catchments. It may be objected that the gauges are not of a standard pattern always; it is quite likely, but a possible 10% error is surely better than an estimate based on the curve connecting two stations many miles away. If the same gauge has been used its readings, and the whole of its records, could be corrected by expert comparison with a standard gauge. For that matter, standard gauges are occasionally seen placed so that trees partially screen them, and great difficulty is always found in obtaining reliable observers. A number of non-official records have already been collected in the office of the Survey.

It is therefore suggested that a large number of additional standard rain gauges shall be obtained and placed in catchments which offer good promise of power. If the localities are such that regular daily observations are impossible the next best expedient is to have gauges that can be read at longer intervals, or self-recording gauges if these are obtainable. It may be observed that the Japanese Government proposes to fix no less than 166 new rain gauge or meteorological stations in the islands for the hydro-electric survey.

Secondly, enquiry should be made through District Officers regarding every private rain gauge of which the records have been kept, and copies of these records should be obtained for the whole period for which they have been maintained. The collating of these records together with those of the official stations will take a considerable time and must be carried out by a trained specialist. The Director-General of Observatories will no doubt be able to advise as to the best method of procedure. Here it is sufficient to point out that the present records are insufficient and that more are urgently required. The rainfall map to be prepared from the official, private and new records should be plotted for each degree sheet of the Atlas of India on the scale of 4 miles to the inch or thereabout. As more data are acquired it should be corrected and brought up to date. The reconnaissances to be undertaken will show the catchments in which new gauges are more particularly required.

33. *Discharges and run-offs.*—(See paragraph 9). Except where required for irrigation projects practically nothing has hitherto been done to obtain the normal, minimum and flood discharges of rivers and streams in India. Still less is the run-off under various conditions known. The staff available for such work is exceedingly limited; the area in one engineer's charge is often very large; and the localities where observations are required are generally far apart and frequently difficult of access. It has already been pointed out that long continued observations are necessary, although those made in a single exceptionally dry year may be very valuable. The past season has been such a one in many parts of India, and suggestions were made before this enquiry began to take advantage of it; but shortage of staff owing to the war, combined with other factors, prevented their adoption. Had this work been put in hand at the time of the first enquiry in 1905 an immense mass of invaluable information would have been collected by now. As it is the Lists of Sites show that nothing whatever is known in the great majority of cases. The Report of the Japanese hydro-electric survey shows that 320 new gauging stations are being established in those islands.

As in the case of rainfall, so here the question of accuracy comes to the fore. The whole principle on which the most approved discharges of streams are calculated is based (See Appendix II) on Bazin's experiments on trapezoidal channels. The coefficients given are probably the best obtainable, but when applied to the bed of a hill stream near its minimum discharge they are mere approximations even in the hands of a skilled observer. Results worked out at two places slightly differing in character—probably neither of them really suitable, although the best that nature has provided—will often differ as much as 10 per cent., although in canals and other "trapezoidal channels" consistent

results are obtained. Considerations of this nature led the late Chief Engineer of this Survey, himself a most experienced observer, to write the "Elementary Note" now reprinted in Appendix I, in which those unaccustomed to take discharges are asked to determine the cross-sectional area of the channel and the central surface velocity and to divide the product by 2 in every case. Such a method, which could be put in practice by any amateur, would give results of infinite value as compared with our present blank ignorance. It is for consideration, in view of the importance of the problem and the urgency of its solution, whether during the next few years it would not be possible to employ selected students from the local engineering colleges on this work, under P. W. D. supervision, during the two or three driest weeks before the monsoon breaks or the snows begin to melt, as the case may be. If the matter is left to the ordinary agency of the Public Works Department the results will assuredly be more accurate, but they will take many more years to collect. Bearing in mind the fact that Bazin's coefficients are not based on experiments on streams of the nature referred to, it will be most valuable if any officer with the necessary experience, stationed where a suitable hill stream exists, could make some careful experiments. It is suggested that a weir should be built from which fairly exact gaugings of the actual flow can be obtained. Then, in the reaches above or below the weir, a number of suitable reaches free from pools should be selected, as uniform as can be found. The type of bed referred to will generally have a hydraulic mean depth of unity or less, during low water at least, and the roughest of beds, with discharges of 10 to 100 cusecs. Cross-sections will then be taken and mean cross-sections plotted in the usual way. The existing coefficients are nominally at least based on the maximum central velocity; but it is suggested that in investigating the matter both this and also the mean velocity from a number of observations at various parts of the channel should be observed. Doing this at several different places with different characters will probably enable arbitrary coefficients to be worked out applicable either to the maximum or mean velocity. In selecting the reaches very little labour will often suffice to even up the width of very small streams and to check back flow. Still water will generally exist in places, but at least coefficients worked out from definite measurements are likely to be less inaccurate than the best now published.

Normal and maximum flood discharges can probably be better determined by means of self-recording gauges, and a dozen of these were ordered by the late Chief Engineer as a start and have been distributed. The type selected was the Stevens Water Stage Recorder, with time scale one-tenth of an inch to 30 minutes and gauge height scale one-sixth, *i.e.*, 2 inches of pencil movement corresponds to one foot of float movement The time-scale is 4·8 inches to 24 hours and the roll of record paper is 25 yards long, thus lasting 6 months. The Hon'ble Mr. W. J. Howley, Chief Engineer, Madras, has also ordered some other types of the same instrument for his own experimental purposes, and information will be available regarding these later on. *Early steps should be taken to order any recorders required for next season's work.*

34. *Reconnaissance of Sites.*—In order to obviate unnecessary work in other directions the first thing required is a general reconnaissance of all the possible sites already brought to notice, or to which attention may be called after the publication of this Report, so as to eliminate those which are certainly worthless at present. Some will be found useless for all time, either because the natural discharge, or the possible discharge from reservoirs (capable of being filled), is too small; or because a suitable head, having regard to this discharge, cannot be developed. Other sites will be written off for the time being because there are better ones in the neighbourhood, or because the cost of their development cannot at present compete with fuel-developed power in the district. Yet another class may prove so remote from power users at present as to be apparently worthless for that reason; but here reconnaissance is needed as such a source may in the end prove valuable for special work not dependant on existing industries. Although, the cost of communications to such a site might be very large it has seldom proved a bar to development if there are sufficient mineral

It is suggested that an effort should be made to carry the reconnaissance of sites as far as possible during the coming season. To this end it is suggested that there should be placed on special duty (*a*) Irrigation engineers for sites where reservoirs may be required, or where irrigation from the tail waters may be involved. (*b*) Mechanical or electrical engineers, acquainted with water power development, for other sites. In this connection the suggestion may be thrown out that Government Electrical Engineers may be made more use of. From an inside knowledge of the work on which they are for the most part employed it is clear that this would offer a far better field for their energies for a time; and they are trained engineers. The assistance already acknowledged from this source in one province was great; and there are other officers who have been actually engaged in the construction of hydro-electric works. Again it may be possible, if early action is taken, to secure the services of suitable engineers from the officers and men of the Territorial Forces who will soon be demobilized. It is almost certain that there are some among them who are engineers by profession and who have prospected for water power elsewhere; indeed applications have already been received from some.

35. *Survey of Sites.*—Reference has already been made to the assistance which it is hoped that the Surveyor-General of India may be able to give, in the matter of continuing the topographical survey to districts at present unsurveyed in detail and of revising old non-contoured maps. It will be necessary to see that there is no overlapping here, as clearly the work done in this way will obviate similar general work by other agencies. On the other hand, the specific survey of known sites is rather an engineering matter, dealing with limited parts of a small area, and this will no doubt be undertaken by survey parties in each province, after reconnaissance has proved whether the site is worth it. The following instruments were ordered by Mr. Barlow from the Mathematical Instrument Office, on the 31st January 1919, to reach India by September 1919, *viz.* :—

Tacheometric Plane Tables, 24″ × 22″ with outfits . .	9
Levels, reflecting Abneys Steward's pattern, in sling leather case .	9
Barometers, Aneroid, 4½″ diameter, bronzed, surveyor's reading between 25″ and 31″ and from 0 to 6,000 feet, in sling leather case.	9
Levels, Ziess, Watts pattern, No. 1, complete with stand in box	57

In addition, the Officer-in-Charge, Mathematical Instrument Office, was advised that the following articles would be required from stock, *viz.* .—

Levelling staffs, Sopwoith	57
100 foot tapes	57
Measuring chains, 100 foot	57

The numbers in the above list were based on an estimate of what would be needed in each province; it seems probable, however, that a far greater number of surveyor's aneroid barometers (paragraph 13) will be required for reconnaissance work during the next year or two, including some for use in the Himalayas reading to 10,000 feet, and a further 20 have since been indented for. Application should be made for any needed.

To select, from the data so far collected, the sites which should be dealt with first is no easy matter. On the one hand it is clear that those situated where an early demand for power is likely to arise should receive preference; but there are few places at present of which this can be definitely stated. On the other hand, the fact that special industries on a large scale may be created where power can be cheaply obtained must not be overlooked. Cheap power is the text of the articles on the Chemical and Metallurgical Industries in the Indian Munitions Board "Industrial Handbook 1919." It is there stated that "As an index to the price of energy permissible it may be mentioned that for calcium carbide it should not exceed 0·10 anna per unit or £3·65 per kilowatt year and for aluminium £5 per kw. year." (Page 131). Elsewhere it is pointed out that in North America and Scandinavia current can be generated from water power at 0·05 anna per unit. It will be long before any new works, under present prices, can reach these figures.

In the opinion of the writer, backed in those cases discussed by that of the late Chief Engineer, the following list represents the lines upon which the

work may best proceed in the various provinces, according to the lists of sites in the Appendixes.

Assam.—General reconnaissance of the Khasia, Jaintia and Garo Hills coupled with specific survey of the Cherrapunji plateau for reservoir sites. The possible electrification of the Pandu Shillong Railway should be borne in mind.

General reconnaissance of the Jatinga and Ka Yeng Rivers and of the Maibang Valley, coupled with specific survey of the most promising of these. Other things being equal, the two former are a good deal nearer the tea districts of Silchar and Sylhet, but a matter of 30 miles is not of great importance.

Bengal.—Survey of the group of Darjeeling streams above the Great Rungit, to ascertain the best of a score of competing sites.

Survey of the upper reaches of the Jaldaka River and tributaries on the British side, coupled with further examination of the problem of electrifying the Duars tea factories.

Survey of the Tista River.

Bihar and Orissa.—A general reconnaissance of sites is essential before it is possible to say which are worth survey. Meantime however the Burhabalong, Sankh and Subarnarika Rivers are almost certainly worth careful investigation and survey.

Bombay.—Within the area of the Tata group of schemes it is unnecessary at present to do further work. The Kalinadi River and the Sharavarti at Gersoppa are clearly indicated for detailed examination and survey.

Burma.—Practically nothing definite is known of the majority of sites in this province, and until further information is collected it is difficult to suggest where to start. It appears worth while making a definite survey for reservoir sites above the Anisakan Falls, for Maymyo needs; and if sites are found the existing scheme should be overhauled completely so as to make full use of the small power possibilities. The Heho falls have already been partly surveyed, and it is certainly worth while completing the work with a view to the extension of the railway and the electrification of its hill sections. A demand for other power seems probable.

Beyond these the following rivers merit reconnaissance as being the ones of which some information is already known: the Bernard Myo, Konwet and Kin Chaung in the Mogok district; the Yetagon falls and Myitnge in the Mandalay region; the Mindon Chaung in Thayetmyo district; the Nam Et, Panlaung and Zawgyi within transmission distance of Kyaukse and Mandalay; the Namma and the Shweli, either of which may be capable of great power, the latter having been stated as worth 300,000 h. p.; the Sittang and Thaukyegat in the Toungoo area; the Tavoy district generally, as there is a power demand there. Three of the largest suggested sources are omitted so far. A large amount of work has already been done in connection with the harnessing of the Irrawaddy rapids, and this should be carried forward to the stage where it is possible to judge what power is available and about at what cost, not in great detail at present but on broad lines. The Kanti falls on the Chindwin and the Hatgyi rapids on the Salween are also worth prospecting, even though they are out of reach of present needs, as they may prove to have great possibilities. The Yunzalin near Papun is also promising.

Central Provinces and Berar.—Here again it is not easy to choose between innumerable projects regarding few of which anything definite is known. Early reconnaissance of all the sites will enable some to be eliminated and others chosen for detailed work. The Balaghat area is the most likely to require power and within reach of it the Nahara and Uskal Rivers seem to offer the most promise; examination will show if either is worth detailed survey. The many streams and reservoir sites in the Melghat area and on the Chikalda plateau should provide some good sites, and these should be examined and if necessary surveyed. The group of schemes comprised in the "Silewani Ghat project" should be examined in detail, together with the Kanhan River, as both are within reach of Nagpur which can absorb much cheap power. The Bina River in Saugor District; the Chornai River; the Chitrakot Falls on the Indrawati as well as the Marble Rocks on the Nerbudda, near Jubbulpore, also merit full investigation.

Madras.—The Periyar project will soon, it is hoped, emerge from the stage of prolonged investigation into realization. The whole Nilgiri area merits further examination including the Kundah River, Karteri and Coonoor scheme, Pykara and Siruvani Rivers. It is understood from the newspapers that definite proposals have been made regarding the development of the Kundah River, which is probably the best site of all these; if so the remainder can wait. The Anamalai Hills, including the Aliyar River, and the Sirumalai Hills should also be prospected and, if the result is favourable, surveyed. The Machkund River in Vizagapatam District appears likely to have great power, which may soon be needed for the harbour developments.

North-West Frontier Province.—If power is required here the Kashmir Durbar can provide it from works already in existence on the Jhelum. It is doubtful if it is worth while to investigate further sites in view of the peculiar conditions.

Punjab.—The project for utilizing the power of the Sutlej near the Bhakra dam site is the first that claims attention. Without endorsing all the statements in the paper on this subject, referred to in the List of Sites, Punjab, it clearly merits further investigation and the drawing up of careful estimates. It appears to be clear that the scheme can in no way interfere with the irrigation dam project, and, if that is so, it should receive every encouragement. Once the dam is built it will be difficult if not impossible to make the tunnel without emptying the reservoir, and a really comprehensive scheme for supplying cheap power to the province will be lost. For this reason also the tunnel, if built, should be of the full capacity required. Should the investigation prove satisfactory it becomes a question of the demand for power within reach. As a "demonstration plant" with good chances of success the late Mr. Barlow considered this one most favourable. Probably if the tunnel and diverting weir were constructed by Government a company would come forward to develop the power.

There are also the many known canal falls in the province, and exact information exists regarding them. If it is known that they are available for development, on easy terms, it seems probable that companies may come forward.

Apart from the above, the whole Himalayan area requires prospecting, including the Kulu rivers and Sutlej tributaries; and the Haro and Jablat Rivers, as to which enquiries have already been made by a firm, should be examined and, if found good, surveyed.

United Provinces.—Certain reaches of the Jumna have already been fully examined and their development may be hoped for. The canal falls are mostly of small power, but their value is also definitely known. Beyond these the Himalayan rivers generally require prospecting and of these the Alaknanda, the Bhagirathi, the Bakher and Belan Nadis, the Nayar and the Sardah seem the most promising. The Karamnasa and Chandrapraba schemes in Benares State also merit detailed examination.

36. *Training in Hydro-Electric Engineering.*—So far as is known the question of training engineers in Indian Colleges in the specialized work of water power has not hitherto been taken up seriously. The impression prevails that water power is a branch of irrigation work which can be taken for granted, but this is not so, although these two branches of engineering run on parallel lines so far as low falls and reservoirs are concerned. The electrical part of the problem of water power is again quite separate, for it will be seen that this Report contains hardly a word about electricity from start to finish. The essentials for an engineer who is investigating water power sites are that he shall have a sound knowledge of mechanical and hydraulic engineering, for power problems cannot be dealt with satisfactorily and thoroughly except by an engineer trained in power problems.

This matter has been receiving attention in Great Britain, as the following extract from the Second Report of the Water Power Committee of the Conjoint Board of Scientific Societies will show. It should also be taken up in India, where at present there are comparatively few engineers trained to deal with water power problems.

"*Training in Hydro-Electric Engineering.*—In view of the great developments in hydro-electric engineering which are inevitable throughout the Empire during the coming decade, it would appear to be of the greatest

importance that the engineers of Great Britain should be prepared to take a commensurate part in such development. In the past large scale hydro-electric engineering has been confined very largely to Canadian, American, or Continental engineers and corporations, and unless some definite and early endeavour is made in this country to make up the leeway, it is probable that the bulk of the Empire's future water-power will be developed outside the country.

"While there is some indication that strong financial and manufacturing interests are now considering such developments, the Committee would draw attention to the lack of facilities in our Universities for giving the necessary specialized scientific training to the young engineer wishing to enter this field of engineering.

"The Committee would emphasize the fact that an adequate supply of suitably trained engineers is essential to the attainment and maintenance of such a position in the hydro-electric world as is commensurate with the importance and capacity of the British Engineering Industry. It attaches great importance to the early provision of training facilities of such a standard as those, for example, at Cornell University, in one or more of the Engineering schools in this country, and would recommend that its views in this matter be brought to the notice of the Minister of Education and of the Secretary for Scotland."

37. *Conclusion.*—It has been the endeavour of the Compiler of this Preliminary Report to collect and arrange in logical order all the relevant information regarding the Water Power Resources of India which is available; to explain in non-technical language the various branches of the subject; and to lay down, in this final chapter, a tentative programme of work that will lead to the successful conclusion of the investigation now begun. While this work is being carried out the interlaced question of industries is in strong hands, and the combination of power and industries is essential to the prosperity of both. At the present time, while prices are high on the one hand, exchange is favourable for the import of plant on the other. There will however be keen competitors in the market for orders, and the British manufacturers of pipes, turbines, generators and switchgear must see to it that they are not left stranded. Hitherto they have been content to take the small orders and to let the large ones go to countries that have specialized in water power. It has even been asserted that engineers from abroad are essential to the proper erection of plants when received. It is high time that these fallacies should be disproved, and His Majesty's Trade Commissioner in India has this matter in hand.

To have acknowledged the source of every item of information in this Report would have increased its volume without adding much to its utility. The thanks of the Compiler are due to all and sundry who have assisted; particularly to Chief Engineers of the Public Works Departments and their Superintending and Executive Engineers; to Conservators of Forests and their Assistants; and to officers of the Munitions and Industries Departments. Above all acknowledgments are due to the late Mr. G. T. Barlow, C.I.E., whose untiring energy stimulated others to give their scant leisure to this work, which an unkind fate did not allow him to complete.

J. W. MEARES.

Simla, 29th May, 1919.

APPENDIX I.

Elementary notes by the late Mr. G. T. Barlow, C.I.E., Chief Engineer, dated 23rd March 1919, on the Preliminary Investigation of Water Power Sites for Electrical Purposes.

1. *Object of the investigation.*—The chief sources of energy which are at present known are coal, oil and water power. The two former are easily handled and transported, and in most places are more convenient and cheaper than water power, but their supply is limited, and their cost must sooner or later increase. A knowledge of the water power potentialities of the country is therefore of the greatest importance, not only in the conservation of energy, but also in the economic development of the country.

At present very little is known about the water power resources of India and Burma, because they mostly lie in the hills and jungles which are sparsely inhabited, and rarely visited by any officials ; only rough survey maps exist of many parts.

The object of the preliminary investigation is therefore to locate the favourable areas and sites, to ascertain the discharges of the perennial rivers, and to collect other information through the Local Officers, which will enable detailed surveys to be carried out expeditiously by a special staff during the cold weather.

The object of the survey is *not* to prepare estimates for town lighting and electric fans, but to obtain details regarding favourable sites that can be made of general use to the Public. These details will show where and approximately how much power is available, and will also give other useful information which will enable any Company that requires power to know where and how to set to work to prepare the detailed plans.

To discover the localities of all the existing water power resources of the country is desirable whether a demand for power exists at present or not. The most unlikely places to-day may in a few years' time be the centres of Industrial, Agricultural or Mining activity. India and Burma are immense countries, but even though this is so, if intelligent and willing assistance is given by the Local Officers it will be possible to eliminate the useless areas, and to concentrate the survey work in the promising localities.

2. *Definitions of technical terms, etc.*

(a) *A typical Hydro-Electric Scheme* consists of a perennial river or of a reservoir or both for the supply of the water; this water, except where a natural fall already exists, is diverted into a separate channel by means of weirs or regulators, and is then run in an open channel along the hill side at an easy slope, or in a tunnel through the hill, till a suitable site has been reached for running the water down the hill slopes and obtaining the requisite fall for power purposes. The water is then run down the hill side in steel pipes to the power house which is situated at the bottom of the hill above the High Flood Level, and finally the water is escaped back into river ; sometimes the water is diverted through a watershed into another river. From the power house transmission lines are constructed to convey the current to the factory or to other consumers. In the preliminary investigation only the details regarding the *supply of the water* and the *height of the fall* are required though details regarding other relevant points will be welcomed.

(b) A *Cusec* means a cubic foot per second.*

(c) *Head.*—The vertical difference in level (in feet) *i.e.*, the height of the fall between the inlet and outflow of water used for power purposes is called the *Head*. In all preliminary works it is sufficient to note the actual head available.

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*Note.—The small water driven flour mills, found in the Himalayas, take from 3 to 4 cusecs. J. W. M.

(*d*) For water power purposes the "fall" means the difference in height between the level of the water where it will be taken from the stream and that at the place where it will be returned to the stream and it may be made by :—

(*i*) a vertical drop in a river or canal,

(*ii*) a series of rapids making, in a short reach of one or two miles of a river, a total fall of so many feet, or

(*iii*) an artificial fall which can be made in a reach of, say 4 or 5 miles, in a river with a *steep* slope, by taking off the water and running it along the hill side at a *gentle* slope, or in a tunnel through the hill to another valley ; and then, at a suitable place, running it down the hill sides back into the same or into another river bed.

For power purposes (*i*) and (*ii*) are merely superior to (*iii*) because the length of flume or open channel to the entrance of the pipe line is cheaper, and more convenient for regulation purposes.

(*e*) *Storage reservoirs* are natural or artificial collections of water situated above the fall, which are commonly called tanks or lakes. The water is collected during the monsoon periods or at other times when there is excess water, and is used for irrigation or power purposes, or for both. These reservoirs, which must be constructed above the fall, provide the necessary discharge in period of low supply in the river, and also collect the water which is running in the river when the water power plant is closed down, or when irrigation is not required.

(*f*) When it is found that a stream dries up or falls very low for a short period before the break of the rains, then in order to maintain a constant power, some storage must be provided.

(*g*) *One cusec running constantly* throughout the year is equivalent to 31·5 million cubic feet of storage, but allowance has to be made for evaporation and percolation losses, so that to obtain the equivalent of that constant discharge a storage of 35 million cubic feet should be provided. For one month the storage necessary may be assumed at 3 million cubic feet and for one day 100,000 cubic feet.

(*h*) The *Catchment area* of a stream at any point is the area draining into the stream at that point.

(*i*) *Watershed* is the boundary line between two catchment areas.

(*j*) The *Electrical Horse Power* that can be generated will be approximately $\frac{\text{Cusecs} \times \text{Head in feet}}{11}$, or $= \frac{\text{Cusecs} \times \text{Head in feet}}{15}$, when expressed in *Kilowatts* instead of Horse power.

3. *Sites suitable for producing power.*—Navigable or tidal rivers or waters are useless for water power purposes, because the cost of development is very great, and the power obtained is small. The power available depends on the product of the fall obtainable and the minimum discharge that can be relied on at the driest time of the year. A navigable river may have a large discharge but the slope of the river bed will be extremely small, and in a reach of 4 or 5 miles it will be impossible to produce more than a few feet of artificial fall. The product of the discharge multiplied by the fall will therefore be small while the cost of harnessing the river, and the cost of the other works will be very great. One thousand cusecs falling 5 feet will give the same power as 5 cusecs falling 1,000 feet, and it will be readily understood that the cost of developing the latter will be far less than that of the former. The best sites are therefore small discharges with big falls; say 50 to 200 cusecs falling 400 to 2,000 feet, but medium discharges of say 200 to 500 cusecs falling medium heights say 100 to 400 feet are also good, while large discharges (say anything above 1,000 cusecs) falling small heights of say 5 to 50 feet are expensive in construction, and therefore poor if anything better is available.

From this it follows that the best sites are generally those found in hilly

The ideal site is one where several small snow or spring fed streams collect in a high level valley above the fall, and then drop many hundred feet in a short length of the stream into a lower valley, where sound rock suitable for a dam is found at the exit of the upper valley; where the run off from the catchment area will be sufficient to provide the necessary storage; and where the valley is flat and uncultivated, which will enable additional storage to be collected by means of a low dam, without destroying cultivation.

All these conditions seldom exist in one place and one has generally to be content with a stream the discharge from which disappears for a couple of months before the rains, or with an indifferent storage site where the valley has a quick slope, and a high dam will be required to store much water, or where the rock is poor, or submergence will necessitate the removal of villages and the payment of heavy compensation for the loss of cultivation, and so on.

In the preliminary investigation however there is no necessity to give great consideration to all these points, it will be sufficient to find a perennial or nearly perennial stream where there is a good fall. The details of the storage site can best be left for expert survey work later on.

Any site is worth considering where the product of the minimum discharge in cubic feet per second multiplied by the height of the fall in feet is not less than 10,000. Anything less than this is too small for industrial purposes though it may be of use for town supply.

4. For preliminary reconnaissance an Aneroid Barometer to measure heights, a watch with seconds hand, and a tape measure or a 10 foot rod are all the instruments necessary.

The points to note are:—

(a) Approximate discharge and Head available.

(b) River and site on river, by reference to the 1″ maps or by latitude and longitude.

(c) Accessibility, *i.e.*, how to get to the site, and nearest road, rail or river communications.

(d) General remarks (when known) on the height that the high flood water rises, whether a storage reservoir appears possible, nature of the country, geological formation, difficulties, market for power and any other points of interest which may affect the cost, construction, or upkeep of the works.

Where it is impossible to observe an accurate discharge, or where the correct methods and co-efficients to be employed are unknown, the following very approximate method may be adopted:—

Select a straight reach of the stream where the flow is uniform and where there are no marked pools, and mark off with pegs any convenient length of fairly uniform width. Then measure as accurately as possible the width of the stream, and find the *average* depth by soundings at intervals across the stream. Then throw into the centre of the stream a small stick and note the time it takes to pass along the marked length; repeat this 4 or 5 times to eliminate errors. Then the run in length in feet divided by the average time in seconds gives the velocity on the surface. Then the cross-sectional area in square feet multiplied by the surface velocity in feet per second and *divided by two* will give the approximate discharge in cubic feet per second.

For instance, suppose the length marked off is 100 feet and the floats take an average time of 50 seconds in passing along this length in a stream having a width of 40 feet and an average depth of $1\frac{1}{2}$ feet. This gives a cross-sectional area of 60 square feet. The surface velocity will then be 2 feet a second and the discharge $\frac{\text{2 feet a second} \times \text{60 square feet}}{2} = 60$ cusecs.

5. A careful study of the largest maps which are available will be found of great assistance in all reconnaissance work. In dense jungle or rough country it is frequently impossible to follow up the course of a stream, and unless the maps are carefully studied it may easily happen that a useful fall or a promising reservoir site is missed. The 1″=1 mile contoured maps are excellent and the 4″=1 mile Forest surveys are even better.

A few examples are given below to indicate the kind of information which can be obtained from maps:—

(*a*) A flat or a steep valley or hill side is shown by the distance between the contour lines. The closer the lines are the steeper the country will be found.

(*b*) The distance between any two contour lines which cross a stream will give the fall in that reach.

(*c*) Absence of village sites and roads or pathways denotes wild or uncultivated country.

(*d*) Numerous habitations on the hill slopes or in a valley in hilly country denote cultivation, and generally springs or perennial water in the streams.

(*e*) When the discharge of a stream is known at a certain point, an idea of the discharge at another site can generally be guessed by a comparison of the catchment areas at the two places.

(*f*) By a study of the nature of the valleys and the hill sides, a fair idea can be obtained of the general nature of the country, and its possibilities with reference to reservoir sites, slopes of the stream, and places where an artificial fall for power purposes can be found.

(*g*) When a stream makes a long hair-pin bend, it is frequently possible to obtain a good fall by diverting the water in a tunnel across the neck of the bend. Several miles of a river can sometimes in this manner be replaced by a short cut diversion of a few furlongs.

(*h*) Sometimes the slopes on one side of a water-shed are very steep, while on the far side they are gentle; when this happens it may be possible to form a reservoir and divert the water through the hill, and by this means obtain a most useful artificial fall.

Addendum to elementary note.

Useful Hydraulic Data (in round numbers generally).

Flow.

1 cusec flow = 1 cubic foot per second = 62·4 lbs. per second,
= 60 cubic feet per minute = 3,744 lbs. per minute,
= 374 gallons per minute,
= 3,600 cubic feet per hour,
= 86,400 cubic feet per day,
= 2·6 million cubic feet per month,
= 31½ million cubic feet per year.

Regulating storage.

100,000	cubic feet	stored	will give	1·16	cusecs	for	24	hours.
,,	,,	,,	,,	2¼	,,	,,	12	,,
,,	,,	,,	,,	4½	,,	,,	6	,,
,,	,,	,,	,,	9¼	,,	,,	3	,,
,,	,,	,,	,,	27¾	,,	,,	1	,,

Main storage.

31½ million cubic feet stored is equivalent to 1 cusec for a year; but owing to evaporation and percolation more storage would actually be required. In round figures:—

1,000 million	cubic feet	stored	will give	30	cusecs	continuously	for a	year.
,,	,,	,,	,,	40	,,	,,	,,	9 months.
,,	,,	,,	,,	60	,,	,,	,,	6 ,,
,,	,,	,,	,,	120	,,	,,	,,	3 ,,

Reservoirs.

1 acre = 43,560 square feet,
1 acre of water 1 foot deep = 43,560 cubic feet,
1 square mile = 640 acres = 27·88 million square feet,
1 square mile of water 1 foot deep = 27·88 million cubic feet, which will (in practice) give a flow of about [illegible] cusec for 12 months, or a little over [illegible] for [illegible] months.

Catchments.

1 inch of rain = 100 tons or 3,640 cubic feet per acre. = 64,000 tons or 2·33 million cubic feet per square mile.

In practice, however, only a percentage, and often a small percentage will reach the reservoir; see paragraph 9.

Power from flow.

On the practical basis assumed throughout this report $\frac{\text{Cubic feet flow} \times \text{head in feet}}{11}$ = electrical horse power.

If 15 is the divisor, the result is in kilowatts.

Power from storage.

(*i*) Regulating. $\frac{\text{Thousands cubic feet stored} \times \text{head in feet}}{42}$ = e. h. p. hours.

If the divisor is 56, the result is in kw. hours or B. O. T. units.

(*ii*) Main. $\frac{\text{Millions cubic feet stored} \times \text{head in feet}}{370}$ = e. h. p. years.

If the divisor is 500, the result is in k. w. years.

APPENDIX II.

Coefficients for ascertaining mean velocity from greatest surface velocity in channels.

Hydraulic mean depth.	Very smooth channels-cement.	Smooth Ashlar or brickwork	Rough channels Rubble masonry	Very rough channels earth	Channels with detritus
Feet ·25	83	79	·69	·51	42
·5	84	·81	·74	·58	·50
·75	81	82	76	63	·55
1	85	..	·77	65	·58
2		·83	79	71	64
3		.	·80	·73	67
4		..	·81	75	·70
5			..	76	·71
6		84	...	77	72
7				78	·73
8			..		...
9			·82		·74
10					...
15					·75
20					76
30					·77

The hydraulic mean depth is found by dividing the cross-sectional area in square feet by the wetted perimeter in feet. The mean values of several cross-sections along the chosen length of channel are used. For most streams and rivers in the hills the coefficients in the last column will be used. It will be observed that with a hydraulic mean depth less than 0 5 foot the coefficient is slightly below the figure suggested in Mr. Barlow's note (Appendix I); this however will almost always give conservative results.

APPENDIX III.

Part of an aneroid survey—see paragraph 13.

The entries in the field note book were as follows:—

Date	Time	Station.	Temp F	Reading of aneroid.	
April 4 .	6 0	I	72	1870	Outward journey.
" .	8 45	II	83	1853	
" . .	10 0	III	92	2055	
" . .	12 0	IV	96	2850	
" .	12 10	VI	91	2972	
April 6 .	5 30	VI	66	3002	Return journey
" . .	7 0	V	69	2150	
" . .	7·30	II	71	1900	
" . .	8·30	I	80	1795	

Reduction by Molesworth's curve for diurnal variation in Calcutta and for air temperature by means of curves given in Molesworth and Deschanel, as follows:—

Outward journey.

Station.	Diff. by aneroid feet.	Correction for diurnal	Result feet	K	Final difference, feet	
I–II	Fall 18	+40	Rise 22	1 096	Rise 24	24
II–III	Rise 202	+3	Rise 205	1 115	Rise 230	
III–IV	Rise 795	−3	Rise 792	1 130	Rise 896	1,264
IV–VI	Rise 122	*Nil*	Rise 122	1 130	Rise 138	
					TOTAL RISE .	1,288

Return journey.

Station.	Diff. by aneroid feet.	Correction for diurnal	Result feet	K	Final difference, feet	
VI–V	Fall 852	−23	Fall 829	1 075	Fall 891	1,157
V–II	Fall 250	−5	Fall 245	1 084	Fall 266	
II–I	Fall 105	−5	Fall 100	1 095	Fall 110	110
					TOTAL FALL .	1,267

It will be seen that while the reduced results between the terminal stations agree very well, giving a mean difference between them of $\frac{1,288+1,267}{2}=$ 1,278 feet, the two common intermediate readings do not agree; between stations 1 and 2 the outward journey gives a difference of 24 feet and the homeward 110 feet, while the discrepancy is balanced between stations 2 and 6, traversed by a different route. Unless the instruments can be carried in special lagged cases, so that the metal work cannot get heated up differently at various parts, these discrepancies will occur. A second instrument carried at this time showed equally discordant results at intermediate stations, and the two did not agree any better *inter se.* No doubt if a long halt could have been made at each station, to enable the instruments to settle down thoroughly, the results would have been more even; but this is generally impossible.

Station I was found by a 4″ Forest map to be at *about* reduced level 990 feet. Adding the mean rise between 1 and 2′ *i.e.*, $\frac{24+110}{2}=$ 67 feet, Station 2 will probably be within 50 feet of R. L. 1,057. Station 3, with only a single reading, is 230 feet higher and the result, 1,287 feet, may be 100 feet out. Station 4 similarly may be taken as about 2,183 feet, with a similar margin. The terminal station 6 is probably within 15 feet of 990+1,278 mean or 2,268 feet, as the results accord well and the Bengal weather reports showed that no considerable change of pressure occurred in the interval; station 5 is about 891 feet, below this, or say 1,377 feet within 100 feet. The reductions made from the second instrument confirm these probabilities.

A subsequent test of the two "compensated" aneroids, one kept in the shade as a control and other placed in the sun, showed that the latter in both experiments rose very rapidly; the relative change due to the temperature changes of the instrument itself were 60 feet and 84 feet respectively in the course of an hour or so. This no doubt accounts for the discrepancies at intermediate stations.

APPENDIX IV.

Mechanical and Electrical Power.

The British, and practically International, horse-power is the power obtained when energy is being expended at the *rate* of 550 foot-pounds a second or 33,000 foot-pounds a minute. Applied to water power, if 330 lbs of water (5·28 cubic feet) are discharged per minute under a head of 100 feet (giving a static pressure of 43·3 lbs. per square inch) the energy expended will be at the rate of 1 horse-power. This, however, is theoretical, or water horse-power, w.h.p. If a turbine and pipe system having an efficiency of 90 per cent. are employed to utilize this flow and fall, the mechanical or brake horse-power obtained on the shaft will be 0·9 b h.p. If this mechanical power is used to drive an electric generator, the efficiency of conversion being 95 per cent. under the particular conditions, the electrical horse-power obtained will be ·9 × ·95 =0·855 e.h.p. The value of the horse-power in foot lbs. per minute is in each case the same, but the fraction available diminishes. The output of the generator, 0 855 e.h.p. × ·746 gives the exact electrical equivalent, *viz.*, 0 636 kilowatt, as 1 e.h.p. =746 watts or ·746 kilowatts. To round up the example, if this ·636 of a Kilowatt is converted to heat (where the efficiency is necessarily 100 per cent.) it will give out ·636 of 57·3 or 36·4 British Thermal units per minute, which is equivalent to 28,200 foot-lbs. per minute, out of the 33,000 with which the example started. Thus horse-power is a *rate*, not an *amount*, so "500 h.p. per minute" is meaningless; the total amount of electrical power generated in any particular time is expressed in e.h.p.-hours or kilowatt-hours. If 500 h.p. (373 k. w.) is exerted for one minute the resultant energy is 500/60 or 8·33 h. p. hours or 6·21 k. w. hours. These elementary explanations are only given because the letters received from engineers show that they are required.

No mention has so far been made of "indicated horse-power" and "nominal horse-power." The former represents the power developed *in the cylinders* of a steam or oil engine, as calculated from the indicator diagram, and will generally be from 7 to 18 per cent. higher than the effective b.h.p. developed on the crank shaft. Nominal horse-power is a term surviving from the earliest days of the steam engine, and is practically meaningless now. The b h.p. of an engine may be two or three times the n.h.p. as the term related to the size of the cylinders and length of stroke without regard to the steam pressure actually used. Where returns for the census of power are submitted in n.h.p. an endeavour should be made to ascertain the b.h.p. developed by comparison with other cases. Otherwise the n.h.p. should be multiplied by 3.

APPENDIX V.

List of sites in Assam.

Bhugai River (Garo Hills).—Unsurveyed in detail, but has a rainfall of 100 inches of which 91 per cent. falls between April and October. Appears unlikely to afford any good site judging by the $\frac{1}{4}$-inch map. The catchment area however is some 85 square miles at Selhat Haut, where the Naranga tributary flows in. (Map 78 K. 7).

Bogopani River.—see Shella River.

Cherrapungi.—see Shella River.

Damring River.—see Krishnai River.

Didram River.—see Jinari River.

Digru River.—see Um Tru.

Dudhnai River (Garo Hills).—Nothing is known regarding this stream, or its tributaries, the Manda and Chichura but it is probably worth reconnaissance as the rainfall is high and the slope rapid. At the junction of the above tributaries the Manda has a catchment of about 10 square miles and the Chichura about 70 square miles. About 105 out of 115 inches of rain falls between April and October. (Map 78 K 13).

Jadukata or Kynshiang River and tributaries (Khasia Hills).—Appears to have considerable possibilities, the rainfall being between 100 and 150 inches of which 94 per cent. falls between April and October. There are many falls, and reservoir sites may be found in the Nongstoin area. The catchment area above the falls of 70 feet, with others near by, in latitude 25° 26′, longitude 91° 8′ is about 24 square miles. (Map 78 O; 3, 7, 10).

Jatinga River.—The possibility of using this river for the electrification of the hill section of the Assam Bengal Railway has been considered by the Agent. The proposal is to dam the river just below the junction with the Ka Yeng (q. v.) near mile 277, up stream of the hair-pin bend near the railway tunnel. (There are no detailed maps of the river area available at present). The area flooded would be about $2\frac{1}{3}$ sq. miles, and with a 90 foot dam and mean depth of water of 45 feet the storage would be some 3,000 million cu. ft. The rainfall is said to vary between 114 and 250 inches in the catchment, mostly falling between March and October. It averages 84 at Haflong and 174 in the Jatinga Valley. The above storage would give about 380 cusecs for the 6 dry months and 12 hours a day. The catchment area of the combined streams is about 96 sq. miles above here. The power station would be near Damchara Station, where a head of about 200 feet could be obtained, with a long canal on difficult ground and perhaps a long pipe line so far as is at present known. The site may be good for 7,000 e. h. p. or more. It seems probable that a higher dam than 90 feet would be required to give the storage indicated, and this might involve the submergence and re-alignment of several miles of the railway in difficult country. The dam site requires further examination. Rock outcrops in several places on both banks, and is hard and compact, with the strata often vertical, sometimes twisted, and frequently broken. It is sound enough for a weir to stand on, but not for water to fall on unless heavily protected. It is probable that the river bed was once 100 feet deeper or more, and the present flat valley has been formed by the hills slipping down on the left bank and blocking the river. A lake was formed and in course of time its overflow has scoured out a new channel, but this is still much above the old level. There is a possible flank escape (not examined) on the left bank some little way back, where rock should be found, as evidently the river at one time escaped by this route. The dam would probably run across the river at a sharp angle, but the line would have to be trenched for examination and this would be most difficult. Further examination in detail is required before a verdict can be expressed on the scheme. See also Ka Yeng River and Maibang. (Map 83 G 4).

Jinari, Jinjaram or Didram River (Garo Hills).—This has not been prospected; it has a catchment area of about 100 sq. miles at Roksaun, with about 100 inches of rainfall, and the slope is rapid. The stream is unsurveyed

on a large scale, but looks unpromising on the $\frac{1}{4}$ inch map. 91 % of the rain falls between April and October. (Map 78 K 5, 9).

Ka Yeng River.—This from the layered maps looks more favourable than the Jatinga river (q. v.), into which it flows just above the site mentioned on the latter. There is apparently a good reservoir flat some 2 or 3 miles from the Railway bridge, but it proved inaccessible in the time available.* The dam here would be well above the railway. The flow was found to be about 5 cusecs only in December, but the rainfall is about 150 inches here over a catchment of 30 sq. miles, mostly falling in 6 months. (Map 83 G 2, 3; unsurveyed).

Kulsi River (Khasia Hills).—This appears promising on the map, but has not been examined. It is a perennial stream and has good falls. Rainfall is 100 inches, mostly between April and October. There are large lakes in the reserved forest area, which could probably be dammed at the exit; but the fall would be that due to the dam only. The catchment area to the lake exit is over 100 sq. miles. (Map 78 O 5).

Krishnai or Damring River (Garo Hills).—Near the Jinari (q. v.) and the same comments apply. Catchment area at Chelteret about 200 sq. miles. (Map 78 K 9).

Maibang, Assam-Bengal Railway, hill section.—The railway station here is in the middle of a large flat valley, several miles long, with steep cliffs on the east side where good rock appears to outcrop. This valley is near the highest point of the line, and it falls steeply away towards Lumding. The valley is cultivated, but the railway could be cheaply diverted. The discharge of the river (name unknown) in December was only a few cusecs, but rainfall is high—about 100 inches. The site is most suitable for a large reservoir, as the valley is flat, the rock apparently good, and an excellent saddle escape exists on the east. This site is considered well worth examination. From the Atlas sheets the catchment area is about 80 sq. miles. (No maps available, but on 78 G 2 or 3).

Monas River.—This flows into the Brahmaputra from Bhutan, and has a large perennial flow. The fall after it enters British territory appears considerable. (Map 78 J 13).

Shella River (Bogopani River in Atlas; Khasia Hills). —This is within the belt of 200 to 140 inches of rain and consists of steep sided gorges, already cut down almost to plains level. Unless reservoir sites are found on the upper reaches in the Cherrapunji district (see General Remarks on Assam; para. 26) it is doubtful if the stream is of any use. If storage exists the catchment areas at almost any point are far larger than is necessary; excess water, not deficiency, will be the difficult problem. The months of December and January are almost dry; November and February receive an average of $2\frac{1}{2}$ inches; March averages 8 and October 15; so the distribution is unusually good. As the country is mostly steep and rocky the run-off will be very high, as all falls are heavy. By way of an index to the dry weather discharges 27 very small feeders of the Shella River were gauged in the area immediately west of Cherrapungi. All these flow into the Um Long and Um Pynjngithuli, which meet at R. L. 1,700 feet, $3\frac{1}{2}$ miles due west of the Dak Bungalow, and attention is called to possible reservoir sites above here in para. 26. January 1919 had only one measurable fall of rain, 0·63 inch on the 20th, and the combined discharges of the streams amounted to only 3 cusecs early in February. That month was quite dry. March had 0·92 inch on the 3rd and 4th only, and the combined discharges later in that month were under $2\frac{1}{2}$ cusecs. April had 13 inches of which half fell between the 17th and 23rd, the remainder being distributed in small falls. The combined discharges taken just after these heavier falls amounted to only 8 cusecs. The Umsohphi reservoir site at the 100 feet contour is just over 1·1 square mile in area by the map. (Map 78 O 11, 15).

Shillong.—A small scheme was drawn up for lighting this hill station from the neighbouring falls on the Um Kra and Um Shirpi, but it offered no facilities for extension beyond about 150 e. h. p. A printed report on the site is in existence. Gaugings of the Um Kra taken at Mawlai Bridge gave from $11\frac{1}{4}$ cusecs at the end of December 1918, dropping very steadily to a minimum of 6·3 cusecs early in April 1919. The decrease is about 1 cusec per mensem in winter. Above Bishop's falls the Um Shirpi dropped steadily from 10 cusecs

* Since examined and found unpromising.

at the end of December 1918 to a minimum of 6·3 cusecs early in April 1919, with the same decrement. (Map 78 O 14).

Umian River, Khasia Hills.—This crosses the main road at Barapani, where a reservoir site may exist. There is however little information as to the fall available below, as the river soon passes to parts of which no detailed maps exist. The catchment at Barapani is about 20 sq. miles. Rainfall about 100 inches, mostly falling in 7 months, *viz.*, about 94 %. (Map 78 O 14 and 83 C 1,2).

Um Kra ; see Shillong *supra*.

Um Rai River, tributary of the Um Tru (q.v.). This has been gauged where it passes near the Gauhati-Shillong road, and where it is perennial. At mile 41 the discharge fell gradually, with large variations, from an average of 20 cusecs in January 1919, and 10 cusecs in February, to 6¼ in March and 5 in the early part of April. The lowest record was 1 cusec. At the Laroh rapids (not identified) the discharge fell from 38 cusecs average in January and 28 in February down to 22 in March; the lowest record being 15 cusecs. Rainfall about 100 inches. (Map 78 O 13).

Um Shirpi.—See Shillong *supra*.

Um Tru or Digru River.—(Khasia Hills). This and its branches, which pass the Gauhati Shillong road, may offer some power, but not much information is available except that the river is perennial and has some good falls. Detailed examination of the maps has not yet been made. The catchment area above the junction with the Um Rai appears to be about 60 square miles, but it is difficult to trace out exactly. Rainfall about 100 inches, of which about 94 per cent. falls between April and October. (Map 78 O 9,13).

Someswari River.—(Garo Hills). Unsurveyed in detail, but looks promising on the layered and ¼ inch maps. At the junction where the Ramthang and Semthang from the west join the Rangdi from the east the catchment areas are about 300 and 170 square miles, or 470 in all. Rainfall over 100 inches, of which 90 per cent. falls between April and October. (Map 78 K 10, 11, 14, 15).

APPENDIX VI.

Bengal and neighbourhood.

Chittagong.—A small scheme was drawn up for utilizing the Karnaphuli River near this town, but no details are available. Rainfall about 100 inches. (Map 84-B, unsurveyed).

Damuda River.—There appear to be some possibilities in this river in connection with an irrigation project, but they have not been investigated from the power point of view. The development would, it is believed, be expensive. The rainfall averages 50 inches in the area. The Port Commissioners of Calcutta are interested in the reservoir project, as the monsoon flush is required to keep the River Hooghly clear. Several reservoirs were proposed, one of the upper ones creating a fall of 100 feet, some of which could be utilized. The lower reservoir, into which the tail waters would discharge, was designed for a capacity of 20,000 million cubic feet; and the river bed below this has a slope of about 10 feet per mile. The prospects are not alluring, owing to the proximity of the coal fields and the high cost of any development. (Map 73-M).

Darjeeling District.—The present plant (See Table 2) is incapable of supplying the whole district and various schemes (Table 5) have been drawn up for further power. None of these are particularly comprehensive and detailed examination should improve on them. The Great Rungeet River is mostly out of British territory; the Little Rungeet River with its tributary hill nalas is in all cases suggested, and these are certainly capable of development. They have a catchment area of about 200 square miles. It is probable that at least 1,000 feet head can be obtained with a minimum discharge, from the Little Rungeet and the Kahill Nala alone, of 40 cusecs. The 2,000 foot contour offers a favourable channel line, and the drop would be made to the Great Rungeet where these streams meet it, at about R. L. 1,000 feet. No storage sites (other than for regulation) are probable, but power to the extent of 3,000 e.h.p. may be obtainable. Rainfall 120 inches well distributed from April to October. The following gaugings were made on the 4th April 1919, when the flow was exceptionally low, at points selected as likely to be reliable, and capable of being combined into a single scheme. The coefficient locally adopted has been changed from 0·66 to 0·5, as the hydraulic mean depth is extremely small and the beds are full of boulders and no really good cross sections are possible; the readings however were carefully made, and the reduced results are dependable.

Raman 48 cusecs; Lodhoma 17 cusecs; Rungriate 4½ cusecs; Rilling 7 cusecs; Little Rungeet 22 cusecs; Kahil 7 cusecs; total 105.

(Map 78 A 7 and 8, survey incomplete towards Sikkim).

Duars District—In addition to the Jaldaka (q. v.) on the border there are to the East some half dozen much larger rivers, mostly snow fed, falling into the Duars and Goalpara from Bhutan. The Amo Chu or Torsa, Chin Chu or Raidak, Sankosh, Saralbhanga, Manas, as well as smaller streams, all come from very high ground and must have great possibilities; but no maps are available, and no prospecting has been done. Probably the power sites will be outside British India entirely.

Jaldaka River.—(or Hidden Stream). This lies on the border line between Kalimpong (Darjeeling) and Bhutan and flows into the Duars; its upper reaches are in Tibet and Sikkim; the road up from Kumani Forest Bungalow is negotiable by elephants for some distance; it crosses and recrosses the boundary, over the river, which is barely fordable to men at the lowest water in April before the snows melt. The main river is apparently fed from the snows of the Jelep La, north of Gnatong in Sikkim; a considerable tributary, the Ne Chu, joins the main river where Sikkim and Bhutan meet the Kalimpong boundary and a fair one on the left bank ½ a mile below. The catchment area here is about 130 square miles. The streams were gauged in the first week of April 1919, when the discharge was believed to be the lowest ever known; it was about 130 cusecs at the junction, where the elevation was found to be about 2,000 feet. The tributaries lower down were nearly dry in March 1919. The rainfall is not less than 150 inches, and the flood discharges are vast, probably over 40,000 cusecs at times. The slope of the bed is fairly

steep throughout, down to the plains near Sipchu Ghat (some 12 miles) where the elevation is about 680 feet. The upper part of the area has not been surveyed, but it is probable that a channel could be taken along the right bank, in British territory, at about contour 2,000, to a point near Kumai Tea Estate, where a drop of 1,000 feet or more may be obtainable—but the lower part of this again has not been contoured. Neither the stream beds nor the hills along the route appear to afford good facilities for even regulating storage, but further investigation is required. If this development is impracticable other sites lower down may not prove so; there are several places where a dam might (with difficulty) be built to impound a fair lake, and the river does not carry much silt normally, but the escape would have to be over the dam. The river appears likely to afford at least 12,000 e.h.p. continuously without any storage. Its possibilities are, however, vastly greater, as if harnessed it would be required for the tea districts of the Duars; Mr. A. H. Abbott of Octavius Steel and Company, who are managing Agents of many of these gardens, first drew attention to the potentialities of the river. Tea plucking does not begin until the first rains produce new leaf; and as soon as the early rains begin the discharge rises. Furthermore, before the tea season is in full swing, the snows begin to melt and supplement the cold weather flow. It is very probable therefore that by the time the power would be wanted there would be from 50,000 e.h.p upwards available; but whether this could be developed at a single site is somewhat doubtful. An artificial channel or flume of large capacity (several hundred cusecs) would have to be carried for many miles along the hill side, across several large tributary nalas, and possibly along precipitous or treacherous ground. As, however, the industry awaits the power the scheme is well worth detailed examination. The submontane tea area of the Duars covers about 1,000 square miles, all within easy transmission reach of the site. Some 90 million pounds of tea are prepared in a season, requiring the equivalent of some 85,000 tons of coal, costing at pre-war rates over 13 lakhs of rupees. The greater part of this fuel, about 60 per cent, is used for drying purposes, to heat air which is driven by fans through the leaf at a temperature of about 220° F. The volume of air required is considerable, but the heating of it electrically, by means of resistance coils, is a simple matter, already done on as large a scale in other industrial drying operations. The power required for this purpose is large, but susceptible of exact calculation. The district is probably able to absorb the whole of the power that can be economically developed from the Jaldaka River, during the season from April to December. (Map 78 A. 12, 16. Partly available on 4" scale; part unsurveyed on border of Sikkim and Bhutan.)

Sikkim.—Messrs Burn & Co., Ltd., of Howrah have obtained various forest and mineral concessions in Sikkim, including the right to develop electrical energy from water power. After investigating a scheme to utilize the Tahung Chu and Zenn Chu at their junction they finally decided to develop power at the Lagyap Pass site, east of Gangtok. The source of power is a perennial stream flowing from a snow-fed lake at a high altitude and eventually finding its way to the Tista River. The site is near a gap on the watershed, through which the stream will be diverted to the west, without a tunnel. It will then be carried along the hill side to where there is a steep drop of 2,000 feet into the Roro Chu or Tahsourche nala. Communications are difficult. The site is estimated to yield some 6,500 e.h.p. continuously at an overall cost of about one-tenth of an anna per unit. (No maps available.)

Tista River.- This is a snow-fed river with a minimum discharge of 10,000 cusecs. The slope of the bed where it enters the plains is about 10 feet a mile for 20 miles; and until well into Sikkim, above the junction with the Great Rungeet, the slope does not materially rise. The river is subject to enormous floods from its 3,000 or more square miles of catchment, and although capable of yielding much power the development would be an expensive one. There is little doubt that a dam would be the only method of controlling the floods and concentrating a fall (*i.e.*, its storage would not be drawn on); and to construct this would offer engineering great difficulties owing to the high minimum discharge. Assuming that a 50 foot head could be obtained by this means, as is probable, this would give some 45,000 e.h.p. continuously; and more than one such place could in all probability be found. The river in its lower hill reaches may be estimated as good for at least 150,000 e.h.p. *at a price* (Map 78-A).

APPENDIX VII.

List of Sites in Bihar and Orissa.

Barakar River: see Usri River.

Burhabalong River (Mayurbhang). Mr. (now Major) C. H. Douglas, late of the British Westinghouse Co., investigated a power site on the upper reaches of this river many years ago, having a fall of some 900 feet, and he expressed the opinion that 40,000 e.h.p. or more could be developed with the aid of storage. It is probable, however, that only a single gauging of the discharge was made, which may have been by no means at the lowest time or in a dry year. The reservoir site at that time was unbroken jungle, and not surveyed in detail. The rainfall in the surrounding plains is 60 inches, of which 90 per cent. falls between May and October; it is certainly much higher in the Mayurbhang hills, which rise to over 3,000 feet. The site has now been re-examined under the orders of the Chief Engineer, Public Works Department, Bihar and Orissa. It is reported that there are two main reservoir sites which will cover over a square mile each and store some 1,200 and 1,000 million cubic feet respectively; while the first of these, situated below the junction with the Bukwa stream below Simlipalgarh, can be increased greatly by raising the proposed dam higher than the 120 feet originally proposed. These sites are 2 and 5 miles above the fall, and smaller regulating dams can be built close to the fall with a capacity of 400 million cubic feet more. The fall itself is 795 feet high but can be raised to 950 feet by carrying a channel along the eastern side for a length of 2,500 feet, thus confirming Mr. Douglas' opinion. It is probable that the site is capable of a development of 10,000 e.h.p. at least, and Mr. Douglas' estimate has not been disproved. (Map. 73 J. 8 and K. 5.)

Durgaoti River, tributary of Karamnasa, Shahabad District. At Kadbar Khoh, 9 miles from the river's source, there were reported to be storage possibilities, but the Chief Engineer finds the valley unsuitable owing to the rocks being much fissured vertically and horizontally. Rainfall 40 to 50 inches nearly all between June and September; catchment area about 27 square miles only. The site is reported by the Chief Engineer to be useless, as the minimum discharge in 1918-19 was only ¾ cusec. The Bichli (Mojhli) site, close to the former, is equally useless and dries up entirely. (Map. 63 P. 11.)

Garrha Nadi, Singhbhum District, at Dutaura, 4 miles north of Dhirol Public Works Department bungalow on Chaibasa-Moholia Road, has been examined. There are good storage possibilities (at heavy cost) and the catchment is large, but the fall is probably not more than 50 feet. The flow was 7 cusecs in February 1919 at this site, where the stream breaks through the hills. It is 4 miles north of the Haldopokhar Road. (Map 73 J. 6.)

Kakolat Fall, Gaya District. This is 10 or 12 miles south of Nawada in the hills running east from the Job Nadi. An article in "Indian Industries and Power" says "At the very minimum this may be expected to yield 25,000 horse power" but it is, on the other hand, reported by the Commissioner, Patna Division, to run quite dry in the hot weather. The discharge was 2 cusecs in February, 1919. Large storage is therefore essential. The catchment area is extremely small and the available fall is only 160 feet. The site is reported as quite useless by the Chief Engineer. Rainfall about 50 inches nearly all falling between June and September. (Map 72 H. 10.)

Kanchi River.—The Raota (or Dasan Ghag) fall, 6 miles south of Taimara, in the 19th mile of the Ranchi-Bandu Road, is about 150 feet. The catchment area is about 260 square miles and the rainfall 50 to 60 inches, of which that falling in June to September is alone of real value. The minimum discharge in 1918-19 was 4½ cusecs. No reservoir can be formed at the fall, but without storage no great power can be expected. A site for a reservoir exists 20 miles above the fall and others may exist. Possibly the fall can be increased also. (Map 73 E. 8, 12.)

Kao River, Shahabad District. Above junction with Kudra, at Tarachandi. Has been examined and site reported by the Chief Engineer as useless. (Map 72 D. 1.)

Karo River, Ranchi District. At Perua Ghag, 6 miles south of Topkara, which is 6 miles from Torpa on the Khunti-Kamdera Road, there is a fall of 100 feet. The catchment area is over 500 square miles, and the minimum discharge in 1918-19 was 1 cusec. Storage is probably available 3 or 4 miles above the fall, which can also be increased by a suitable take-off. Rainfall about 50 inches, mostly between June and September. (Map 73 F. 1.)

Mohana River.—Tributary of Phalgu river, Hazaribagh District, 10 miles south of Grand Trunk Road. The Tamasin and Harikhal falls have been examined, and there appear to be storage possibilities 10 miles above Itkhori and possibly elsewhere. The falls are 50 and 60 feet respectively, and extra head can be obtained by taking off at Itkhori. The catchment area will be about 200 square miles at this site. The minimum flow is negligeable. Rainfall 50 inches, of which only that between June and October, amounting to 92 per cent. will be of any real use. (Map 72 H. 3, 4, 8.)

Nindi River.—There is a 200 foot water fall at Mauzah Nindi, Thana Bishunpur, 4 miles north of Serandag and 10 miles east of Bishunpur. The catchment area is about 12 square miles only, but the monsoon rainfall is 50 to 60 inches by the map and probably more on the crest of the hills. Storage will be essential and the site will probably not allow of sufficient to be of any use. (Map 73 A 7).

Papaharan River, Padampur Zemindari, Sambulpur District. The Narsinghnath or Kapildhar fall, 97 miles south-west of Sambalpur, and 20 miles south of Padampur is about 900 feet all told, but the catchment area is only 2 square miles with a minimum discharge of about 1 cusecs. It had previously been reported that the fall came from "a vast sheet of water at the top of the hill"! The stream, however, is sacred, and the Narsinghnath temple is below the main fall, so it is impossible to utilize the site. (Map 64 P. 1).

Phuluaria River, Shahabad. Has been examined at Zibhar Khund, where there is a fall of 450 to 500 feet, but the discharge is very small and storage impossible. The site is useless. (Map 63 P. 9.)

Sankh River.—There is a site under examination 3 miles from Rajdera, on the southern end of the Pakripat-Natarhat Plateau. The catchment area is only 32 square miles with a rainfall of 60 inches, confined almost entirely to June to October. The Rajdera fall is 175 feet and it is believed that a reservoir can be formed above it, increasing the practicable head by tunnelling through to the river. There are mines near. The power is unlikely to be sufficient for alumina reduction, but bauxite is found within reach. The minimum discharge in 1918-19 was only $\frac{3}{4}$ cusec (Map 73 A. 3).

Ibid.—The Perua Ghag fall lower down the Sankh River, 12 miles north of Kochdega and 4 miles east of Kundra on the Gumla road, is about 23 feet, and the catchment area here is over 900 square miles. The bed some miles above the fall is wide and a reservoir site may exist, but storage would be costly. The fall is dry except in the rains, being on a loop of the river, but the main discharge is reported as having been not less than 144 cusecs in 1918-19. (Map 73 B. 5.)

Son River.—It is stated by the Chief Engineer that any storage scheme on any tributary of this river might be of value for irrigation for the Son Canals.

Subarnarika River.—The Hundrughagh fall, of about 312 feet, is 13 miles north of Angara at the 61st mile of the Ranchi-Purulia Road and 20 miles from Ranchi. Extra fall can be obtained by taking off 4 or 5 miles higher up stream. The catchment area is roughly 500 square miles with rainfall between 50 and 60 inches, nearly all falling between June and September; and the cold weather discharge is about 60 cusecs, falling to a minimum of 12 in 1918-19. There is no suitable reservoir site at the fall, but many higher up, all expensive however in arranging for surplus flood water. Probably the site is capable of giving 1,600 e. h. p. or more. (Map 73 E 7, 11, 15.)

Another site has also been examined 4 miles west of Chandil Village, where a storage site exists requiring a dam 600 to 1,000 feet long, to store an enormous volume of water up to 100 feet above bed without flooding the railway. Here the catchment area is over 2,000 square miles. There is a subsidiary site lower down, which might serve as a permanent dam to give the necessary head and two possible additional storage sites further up stream. The cold weather discharge is fair, but the stream must occasionally run dry in the hot weather,

[illegible]

as the dam at Sakchi has no flow at times. Rainfall 50 to 60 inches, mainly confined to June to September. The site will be very expensive to develop, and the power could not compete with waste gas from the Sakchi furnaces. (Map 73 J 1 and 5).

Usri River.—Hazaribagh District. At Usri, about 7 miles from Giridih, just below the crossing of the Gobindpur road, a fall of about 180 feet is obtainable where the junction with the Barakar river is. A good storage site exists above and has been surveyed by the Bengal Irrigation Department in connection with the Damodar flood regulation. Believed to be worth some 1,200 e. h. p. which would be useful for the construction of the neighbouring dam on the Barakar River. Of the total rainfall of 50 inches 86 per cent. is due to the June-September monsoon. The proximity of the coal fields renders it unlikely that the fall will be used. (Map 72 L 8.)

APPENDIX VIII.

List of Sites, Bombay.

Bhatsa River.—There are said to be falls in this river at the site indicated near Shahapur, but no details are known except that the rainfall in the catchment of nearly 400 square miles is very high, probably 200 inches or more in the Ghat area, from local information, though there are no records of the Meteorological Department there. It practically all falls between June and September. (Map 47 E 7.)

Gangavali River.—The Magod falls on this river are said to be 800 feet high and have a catchment of about 280 square miles with good rainfall of from 30 to 75 or possibly 100 inches. No details as to minimum discharge. The rainfall is heavy during June, July and August, but there is generally a fair fall in May, September and October also. (Map 18 J 9, 13).

Igatpuri,—Western Ghats. There are possibilities of a further storage project here (site not identified), but it is unlikely to be developed until the present Tata schemes have all materialized (See Andhra Valley; Nila Mula; Koyna). Rainfall 75 inches or more, and over 100 in parts, nearly all falling between June and September. (Map 17 E.)

Indus River.—If the proposed barrage at Sukkur is built there may be considerable power available and high level irrigation may afford an outlet for it. It is too early to discuss this.

Kalinadi River.—The Borkund falls are said to be worth examination; also the Vincholi falls, and lower still, the Lalguli falls of 500 to 850 feet according to length of canal The catchment is in the high rainfall district of the Western Ghats, *viz.*, 100 inches or more, and is about 280 square miles in area at the junction with the Dogi, near the lowest fall; but the minimum discharge is not known; it was 200 cusecs at Lalguli in the summer of 1905, date not given. A fall higher up the river, near Londa, is also believed to exist; probably this refers to the rapids at Supa, which have been surveyed for power required at Dandeli, as proposed by the Conservator of Forests, Southern Circle. The area has considerable industries, and the tail waters could be used for irrigation. The Executive Engineer, Kanara, estimated (in 1905) that with storage the Lalguli falls were able to give 60,000 e. h. p. but further investigation is required. (Map 48 I, 7,11,12).

Koyna River Project.—This is already entered in Table 5 as having been investigated by Mr. A. T. Arnall The catchment area is 346 square miles in the Western Ghats. The proposed Helwak Lake will have a draw-off capacity of 120,000 million cubic feet, giving 300,000 e. h. p. continuously. The water will be tunnelled through the watershed and the head is 1,600 feet. Rainfall said to be 150 inches, though shown on the 75 inch contour in the rainfall chart; but the precipitation at the edge of the Ghats is extremely high all along. (Map 47 G 10, 11, 14, 15.)

Malapraba River.—Belgaum District. There are falls in this river at the point indicated, but no details are known at present. The catchment area is about 250 square miles and extends through the zones of 30 to 100 inches rainfall, which mostly falls between May or June and September. (Map 48, M, 1.)

Mula River.—There are two rivers of this name. One is dealt with under the Nila Mula Project below. The other rises in the Trimbak hills, which have a rapid drop from about 5,000 feet elevation down to 2,000 feet. The catchment area at the site indicated appears to be about 180 square miles, with a monsoon rainfall averaging 30 to 40 inches but probably far higher in the upper reaches; it is confined however to the monsoon period. (Map 47 E 11, 15.)

Nila Mula Project.—This is already entered in Table 5 as having been investigated by Mr. H. P. Gibbs. The catchment area is 111 square miles in the Western Ghats, and the proposed Nila Mula Lake is estimated to have a draw-off capacity of 18,000 million cubic feet, giving 150,000 e. h. p. for 8,600 hours per annum, so that for tabular purposes the power may be given as 75,000 e. h. p. continuously. The water will be taken through the watershed

Nira Canal Project.—Poona. See Table 5. After the new Bhatgar Dam is built much more power will be available, especially if the Vir Tank is enlarged to pick up the tail waters and store them for irrigation. The Ing falls or rapids also appear to offer some power for 8 months; some 1,700 e. h. p.

Pravara River.—Rises in Trimbak hills near the Mula River (q. v.) and has the same characteristics. The Randa falls have about 200 feet drop and are said to be able to give 3,500 e. h. p. continuously. The site appears promising from the maps, and the monsoon rainfall is said to be very high, from 150 to 200 inches. The catchment at the point indicated appears to be about 80 square miles. (Map 47 E 10 and 14.)

Sharavati River.—District Canara. The Gersoppa falls on this river have a drop of some 800 feet, and it is believed they have been examined for power, though no details have been received. The falls are within 20 miles of the sea and near Bhatkal Harbour, which is under investigation as a port. The monsoon rainfall is from 75 to 100 inches during June to September in the catchment of about 150 square miles, and reaches 150 inches over part of the Ghat area. (Map 48 J 12.)

Tadri River.—The Lushington falls are said to be 300 feet high, and are worth investigation as no discharges are known to have been taken. Monsoon rainfall between 100 and 120 inches over a catchment of perhaps 250 square miles; reservoir sites may be found. (Map 48 J 11 and 15.)

Vaitarna River.—There are waterfalls in this river at the site indicated by the map, north of Tansa Lake, but no details are available. The rainfall (mostly between June and September) is upwards of 75 inches and the catchment of the order of 200 square miles. (Map 47 E 2, 6).

Canal Falls, Bombay.

Canal	Position.	Fall in feet	Minimum flow except at closure cusecs	Working period in days
Gokak Canal				
Wadaihatti Branch . .	Mile 5/7	4	10	240
,, ,, .	,, 6/3	5	10	,,
,, ,, .	,, 6/6	3½	10	,,

It is possible that these falls might be combined, no information is available

Canal	Position.	Fall in feet	Minimum flow except at closure cusecs	Working period in days
Pravara Left Bank Canal.				
Fall No 1	Mile 34	4¼	114	325 (4 closures of 10 days)
,, 2	,, 35	12½	114	,,
,, 3	,, 36	9	114	,,
,, 4	,, 36	4½	114	,,
,, 5	,, 43	9½	58	
,, 6	,, 43	14¾	58	,,
,, 7	,, 44	10	58	,,
,, 8	,, 45	7	50½	,,

Combinations of falls are apparently possible here also.

APPENDIX IX.

List of Sites in Burma.

Anisakan River, Maymyo, tributary of Myitnge. The Deitdawgyi falls on this river have a drop of about 1,000 feet, almost sheer down, and the minimum discharge is said to be about 2 cusecs in May. The catchment area is quite small, of the order of 20 square miles. There are possible reservoir sites, though these have not been surveyed, close to the falls. One appears to be 30 to 40 acres in area. It is possible that other small streams can be diverted into the catchment. No canal is required and a short pipe line only. There is little doubt that such power as is required in Maymyo can be obtained at reasonable cost from this project, 200 to perhaps 500 e.h.p. The rainfall is about 50 inches; 96 per cent. of this falls between April and November, and a considerable carry-over will be required from storage, especially as crops probably absorb most of the small flow in the dry months. The stream is also called Nadaungya Chaung. Minimum discharge in 1919 was 2 cusecs at Htonbo near Sedaw. (Map 93 C, 5.)

Balu Chaung; See Laimaw River.

Ban Chaung.—See Tavoy.

Bean River.—Tavoy. Mr. Crossley of the Southern and Boundary Burmese Wolfram Co., has located an 1,100 foot fall on this river, but no gaugings are available. (Map 95 J. 12, K. 9.)

Bernard Myo River.—This river, 9 miles north of Mogok, is said to have a minimum discharge (due to springs) of 20 to 40 cusecs, and a good drop, stated to be several thousand feet in a short distance. It runs into the Kin Chaung, a tributary of the Sweli, and is probably capable of 8,000 e.h.p. or more. Rock is gneiss and limestone. Rainfall between 100 and 50 inches, of which 96 per cent. falls between May and November. The catchment area is about 120 square miles. (Map 93 A 8.)

Bilin River.—South west of, and on road to, Papun; said to be worth examination. An isolated river, with seven months' rainfall of 100 to 150 inches over its catchment and 5 dry months. The drainage area above Yinon, (which may however be near sea level) is about 600 square miles. It runs nearly dry for 3 months, so storage would be essential. (Map 94 G, but mostly unsurveyed.)

Chaungmagyi. See Madaya R.

Che Chaung.—Yaw district. A promising gorge with a good perennial discharge is found 4 miles above Yeshin village, 45 miles from Pauk.

Chindwin River.—Tributary of Irrawaddy. Kanti Fall (presumably at the place of that name, latitude 25° 58′, longitude 95° 45′) is said to have a discharge of about 3,000 cusecs in March and a fall of 30 feet. It is in wild country, with rock soil, but is said to be the most promising site on the river. May be valued at a probable 10,000 e.h.p., but has not been examined. Mr. Barlow considered it well worth investigation. The catchment is very great, probably 5,000 square miles, with rainfall about 75 inches. (Map 83 O, but unsurveyed).

Heho River.—Beyond Kalaw on the road to Yawnghwe. There is here a very large and almost flat valley, mostly cultivated, evidently an old lake bed, spongy peat like soil, with outcrops of inferior peat. The area of this flat valley (a small part only of the catchment) may be about 20 square miles, but at its lower end, where the drainage escapes, there is a smaller flat of about a square mile (dimensions not determined) partly enclosed by spurs coming in from either side. At the south west end of the large valley a big spring comes through the limestone and feeds the nala that drains the area. The discharge was estimated to be 150 cusecs early in February, 1919, and was gauged at 103 cusecs on the 28th of that month. It was again gauged on 28th April and found to be 64 cusecs, which may safely be taken as near the absolute minimum. At the exit through the hills into Yawnghwe, from the smaller flat referred to above, there is a rapid series of cascades giving a drop of 672 feet in a horizontal distance of 4,000 feet, but it is believed that there is a further fall of 100 feet or more within easy distance, the survey having terminated at the foot of the fall. The nala flows into Imle Lake. The ground on either side of the fall is fairly

good and is suitable for a duct, and the pipe line would be reasonably short. A small regulating tank could be made at the head of the fall and a reservoir of large size above this could be scoured out hydraulically when power is available. Possibly levels may prove that a dam at the head of the fall would impound a considerable volume of water in the small flat valley without flooding the larger valley. The cross-section at the dam site is very favourable so far as it has been taken, showing that a height of 28 feet above water level could be obtained with a crest length of only 240 feet (much greater height is practicable), with rock on one bank and, almost certainly, near the surface on the other. As however there is a drop in this valley of only 14 feet in the 6,000 feet above the fall it is fairly certain that a dam of any size would flood valuable land in the larger valley. If however a power scheme were developed at this excellent waterfall the problem of large storage could be solved quite simply by utilizing a small proportion of the total power in driving large low-lift centrifugal pumps, to keep the upper valley clear, an earthen embankment being constructed at the neck across the smaller valley. Thus, suppose the main dam to be 30 feet high, giving a water level at the neck 16 feet above the stream level. Then the pumping through the embankment at this point would only require about one-thirtieth of the total power available, based on the relative main and pumping "heads." If the nala were liable to violent floods such a scheme might prove impracticable, but this is not the case. The total catchment area is perhaps 150 miles, with an annual rainfall of about 40 inches, of which 97 per cent. falls between April and November. The great flat spongy valley involves a very slow run-off, and considerable evaporation from its swamps, so that the stream (and examination confirms this) is comparatively even in its discharge. It may be hazarded to average not less than about 150 cusecs throughout the year. Before the amount of storage which can be obtained, and the steady flow which can thus be depended on, can be determined, further information is required regarding the actual rainfall and run-off and the capacity of dams of different height with their corresponding embankments. It is also necessary to survey both banks for the best location for a channel from the head of the fall to the point where the pipes would be carried down to the power station; to survey the most practicable pipe line in each case; and to determine from these which bank should be used and where the power station will be located.

The minimum flow will give some 3,800 e. h. p. continuously, which would allow a plant of about 8,000 e. h. p. on ordinary 12 hour working. At the lowest estimate storage coupled with the much greater normal discharge would give at least half as much again. The scheme appears to be a first class one of about 10,000 e. h. p., which would not be expensive to construct, and it should be fully investigated. There is, however, no likelihood of the power being required in the district unless an industry is founded on the power. The Kalaw railway will soon be extended up to the site, and there is considerable traffic awaiting it. The site was examined by Messrs. Barlow and Meares and subsequently discharges and a preliminary survey were carried out by Mr. F. A. Clift, Executive Engineer, Taungyi. (Map 93 D. 10,14.)

Heinza Chaung.—Tavoy. There are falls "of great height and volume" north-east of Yebyu.

Indawgyi Lake.—This has an area of some 40 square miles, and a low dam would impound an immense volume of water. There is a perennial flow from it down the Indaw Chaung, and regulation would be easy. The available fall is not known; nor is the catchment area and rainfall. (Map 92 C. 7,8.)

Irrawaddy River.—Reference has already been made to the British Water Power Committee's remarks on this catchment. Having seen their figures Mr. T. Hare, Executive Engineer, Public Works Department, drew up a scheme for harnessing the river at the defile by damming it below Sinbu. He proposed to divert the river by a channel to the east, *viâ* the Nainsang and Mole Rivers, a distance of 45 miles. The scheme would be both expensive and difficult to construct, with this diversion, a large flooded area with the submergence of many villages, new roads required, etc. The floods rise 60 to 90 feet in the defile so that it is improbable that with any reasonable dam a head of more than 50 feet could be obtained. The minimum discharge is not known. Above Myiti-

kina there is doubtless great power available, at a cost which is likely to be prohibitive.

Kainggyi Ye Ta Gon in the Tawnglet circle of Monglong sub-State, Hsipaw has been mentioned. (Map 93, B, 7)

Kaladan River.—Akyab. The upper reaches stated to have possibilities. The catchment area is over 3,000 square miles at Kaladan, where the Mi comes in, but the elevation there is unknown. Rainfall 100 inches, 97 per cent. falling in 8 months. (Map 84 B. C, and G. unsurveyed.)

Kalonta Gorge.—See Tavoy.

Kelaung River.—Mandalay district. Said to be worth reconnaissance near Wetwun.

Kin Chaung River, tributary of Shweli, near Mogok. Above the junction with Bernard Myo (q. v.) this has a good catchment of about 1,200 square miles, including the Bernard Myo and Konwet, and a good perennial discharge, with several places said to have a good drop also. Below the junction there is also a likely site. Where the Kin Chaung crosses the road the R. L. is about 500 feet whereas 3 miles further up it appears to be about 1,100 feet. Rainfall about 100 inches, 96 per cent. falling between May and November. (Map 93 B. 5)

Konwet River (near Mogok) is believed to have a perennial flow of 20 cusecs and a drop of 2,000 feet in a few miles. From the map the site appears good, but the catchment is not known. If the streams at Mongmit make it up it is about 400 square miles, but this has already been included (rightly or wrongly) in the Kin Chaung. The river joins the Muik, (?) a tributary of the Shweli. Probably good for 3,000 e.h.p. Rainfall about 100 inches, of which 96 per cent. falls between May and November. (Map 93 A. near square 12.)

Kun Chaung, Toungoo. Said to have possibilities. Its tributary, the Sinmakadin has falls which are believed to be promising.

Kyan kpyu Chaung.—See Tavoy.

Laimaw River.—Or Balu Chaung enters Imle Lake near Indemze and is said to have a good discharge and many rapids about 7 to 10 miles from the south-west end of the Lake. Considered capable of 2,000 e.h.p. Rainfall 40 to 50 inches of which 97 per cent. falls between April and November. The catchment area appears to be about 370 square miles up to the valley, but the Atlas sheets show some of the streams apparently flowing both ways! For this reason many of the catchments may have been wrongly estimated. They can be checked by larger scale maps later on. (Map 93 D. 14,15.)

Lampar River.—Said to be perennial with a large fall.

Lenge Chaung, Meiktila, Div. Minimum discharge at Pweya Se was 2·75 cusecs on 29th April 1919.

Lenya River, below Mergui; said to have power sites. Rainfall about 160 inches, lasting from April to November, with a catchment at Lenya of some 700 square miles. (Map 96 I 15, 16.)

Madaya River, or Nam Pai, tributary of Irrawaddy. This has a minimum discharge in the hot weather of about 100 cusecs near Mandalay. Higher up, some 10 miles, the river is said to have a good slope, so power should be found. Near Mogok it is also said to have a good discharge and rapid fall. Rainfall between zones 40 and 100 inches, practically all falling between May and November. The catchment area at Gwe Kyaung is about 1,200 square miles, but the altitude there is not known. The minimum discharge in 1919 was 350 cusecs on the 19th May at the headworks of the Mandalay Canal. (Map 93 B.)

Magyi Chaung.—Tributary of Madaya, 45 miles from Mandalay; this and other similar streams near had a fair discharge (about 50 cusecs) in March and possibly several could be run together for a fall. No details. Site not identified. Elsewhere the Chaung Magyi is identified with the Madaya (*q. v.*)

Man River, tributary of Irrawaddy. This is said to have some possibilities below Ngape but is very little known. It is near the Mon River and has less discharge; and may even dry up at times. A discharge taken near Payagyi village, 12 miles above Aingma weir, showed 40 cusecs on April 7th 1919. A fall may be got by tunnelling through the watershed, it is believed. Very unhealthy till January and of doubtful value. Rainfall 50 inches or more over a catchment at Ngape of about 250 square miles, (Map 84 L 8 and 12.)

Mandalay District (see also Anisakan River). From the headworks of the Mandalay canal the Yetagon waterfall, flowing into the Madaya, can be seen some 6 miles off to the N. N. W.; 40 miles from Mandalay and 35 from Maymyo. There is a drop of 1,700 feet, and Mr. Scott, Executive Engineer, found a discharge on the 9th March 1919 of 14½ cusecs. The minimum, on 12th May, was 5 cusecs. The catchment is only about 8 square miles. Reservoir possibilities are poor, as the limestone is very fissured, but a site north of Yonbin village might carry 100 million cubic feet. The site appears good for 2,000 e.h.p. Rainfall about 40 inches, of which 97 per cent. falls between April and November. (Map 93-B 2, 3, 6, 7.)

Mandalay District.—There is said to be a perennial stream with a large fall some 35 miles north east of the town, not far from Mogok. No details, but probably refers to Madaya or Magyi Ch. (q. v.).

Manipur River, tributary of Myittha. Subject to high floods, and has a quick slope, but in very wild country and unlikely to offer much steady power, though stated to be worth 4,000 e.h.p. Rainfall 50 to 100 inches, over a catchment of some 4,000 square miles, including the considerable Loktak Lake, near Imphal. (Map 84 E & F., unsurveyed.)

Menyan River.—This has not been identified, but is said to have a perennial discharge and a good fall 20 miles from the Irrawaddy.

Mindon Chaung (or Mu) River.—Tributary of Irrawaddy, Thayetmayo District. The upper reaches of this river are stated to be worth examination, and good for 2,000 e.h.p. The lower parts are navigable and useless for power. The rainfall varies from 40 inches up to 100 near the watershed, of which 95 per cent. falls between May and November. The catchment area above Mindon is about 600 square miles. Discharges are available from 1893 The minimum on record is 95 cusecs at the Shwebo Canal. (Map 85 I.)

Minpaw.—A 30,000 horse power scheme was mentioned, working on a 280 foot fall, but it has not been identified so far.

Mon River.—Tributary of Irrawaddy, said to be perhaps worth prospecting as discharge is generally good (seldom below 300 cusecs) and slope quick in upper reaches. Very little information available, as the region is inaccessible and unhealthy until January, but a possible 6,000 e.h.p was suggested. From Kyion downwards, above the canal headworks, it is believed that excellent reservoir sites can be found to carry over the low water period, and from 2,000 to 10,000 e.h.p. can be obtained. A discharge taken at the end of April 1919, gave 279 cusecs above the Dwe junction and on the 5th May 450 cusecs at the canal headworks, Mezali, 40 miles lower down. Regular readings are taken here. Some of the tributary streams look favourable on the map, especially one which joins near Dwe. This tributary joins the river above Paiksok, and carried 48 cusecs at the end of April 1919. The *total* catchment here is about 800 square miles. Rainfall in upper reaches 50 to 75 inches. (Map 84 L 2, 3, 7).

Monghang River.—Southern Shan States. A natural limestone tunnel exists here with a fall of several hundred feet. It is about 150 miles south east of Taungyi, a cart road existing as far as Mongnai. River not identified, but probably on map 94 I.

Moulmein to Pegu.—The hills near the railway are said to offer possibilities by running through the watershed from reservoirs on the east to the coast side. The rock is good. Rainfall probably over 150 inches, mostly falling in May to October. Detailed examination of maps will be necessary. (Map 94 C G. H.)

Mu River.—See Mindon Chaung.

Myittha River.—Tributary of Chindwin. Near its junction with the Chindwin River this (which includes the Manipur River) is said to have a series of rapids and a large discharge, but it is of doubtful value except in upper reaches. Probably 3,000 e.h.p. could be obtained. The lower reaches are at times navigable. Rainfall 40 to 75 over very large catchment (of the order of 10,000 square miles), but concentrated into about 6 months (Map 84 I, mostly unsurveyed.)

Myitnge River.—Tributary of Irrawaddy. There are falls above Theebaw which could be increased, coupled with good perennial flow. This river is said to be "full of power sites." The discharge in March was about 10,000 cusecs

in the reaches near the Mandalay-Maymyo Road. Some 25 miles further up there is said to be a promising "hair-pin" bend. The floods rise about 30 feet and a dam would be most difficult to construct, but a tunnel across the bend appears simple. (This is similar to the Sutlej Scheme.) The tributaries of this river are worth gauging and examining, (See Nam Tu, Namma and Nam Laung below.) The rainfall over the whole catchment of some 8,000 square miles at the junction of the tributaries named is probably about 40 inches. Minimum discharge in 1919 was 6,360 cusecs on 16th May at Kimbet. (Map 93 B and F.)

Nandaungya Chaung; see Anisakan falls.

Nam Et River.—Tributary of the Nam Laung and the Myitnge, 60 miles east of Kyaukse, said to have 1,000 feet fall and a large discharge. By making a dam or tunnel the river, it is said, could be diverted across to the Zawgyi, through a hill, to give some 6,000 e. h. p. Rainfall about 40 inches of which 94% falls between May and November. The catchment area at latitude 21° 35′, which is probably near the place referred to, is about 1,000 sq. miles. (Map 93 C 10, 14 with G 1, 2).

Nam Kaw, falling into the Salween below Na Hang. (Map 93 J, 11.)

Namkwe Lake, north of Yamethin. There is a project here but no details are known. The Executive Engineer, Meiktila Division, proposes to examine it.

Nam Lan River.—Northern Shan States. Said to be worth reconnaissance between Namtu and Mongtung.

Nam Laung River.—Tributary of Myitnge. There is said to be a natural bridge and a 15-foot drop about 12 miles above the junction with the Nam Tu, but the prospects of power do not seem good. The Nam Et flows in above this (q. v.). Rainfall about 40 inches. The catchment at the junction mentioned is however about 3,000 sq. miles. (Map 93 F 4 and 8).

Namma River.—This joins the Namtu (q. v.) below Mansan Falls, and some 12 miles from the junction there is said to be a site with a fall of 200 feet and a minimum flow of about 600 cusecs, equivalent to 11,000 e. h. p. There is also a possibility of making a large reservoir a little distance above the natural bridge that gives the drop in this river. The rock however is limestone and may be fissured. A further site 20 miles due west of Hsipaw was mentioned. Coal (poor quality) is found near this river and there is also iron ore. Rainfall probably 40 inches. The catchment area at Namma is about 100 sq. miles. (Map 93 F 10 and 14 and J 2.) The Nam Hawm or Namhsawn tributary on map 93 J, 5, above the junction with the Namma, is also mentioned.

Nampai River.—See Madaya River.

Namparga River.—(Tributary of Chindwin River). Said to have a fair discharge with quick slopes. The rock is largely sandstone with some shale. Not identified but stated to be good for 2,000 e. h. p.

Nam Pawn River.—Tributary of Salween. Navigable up to latitude 19°, but has a large perennial discharge and probably has rapids in upper reaches. There are falls between Hsataung and Karenni, but not of great height. Rainfall 40 to 50 inches. The catchment area above latitude 20° is some 1,000 sq. miles. (Map 93 G. H.)

Nam Tang (or Teng) River.—This is a tributary of the Salween and 70 miles east or north-east of Taungyi it is said to have large falls at about 97° 45′ by 20° 20′ to 20° 55′. There is a "good discharge" and the road from Taungyi passes near by. Rainfall 40 to 50 inches of which 97% falls between April and November. The catchment area above latitude 20° is about 2,500 sq. miles. (Map 93 H 11, 15).

Nam Tay River.—Tributary of Salween. Said to have good discharge and high falls. No details. Site not identified. Possibly the Nam Tang (q. v.).

Nam Tu River.—Tributary of Myitngye. Already being developed at the Man San Falls (see Table 4). There are many rapids all along this river, which has a large perennial discharge, but it is unlikely that any other equally favourable site exists. Immediately below Nam Tu the low water discharge is estimated as 15,000 cusecs and a fair head may be obtainable. There is also a possible site 12 or 15 miles above the railway bridge over the river, accessible from Hsipaw. Near Hsipaw where the Nampu (?) Chaung joins the Namtu there are said to be good possibilities and power may be wanted. At Makyeng some [illegible] miles above Namtu town, it is said that 1,500 h. p. can

be developed, but the falls are mostly small and would be expensive to combine. Rainfall about 40 inches with a catchment area, at the junction with the Namtu, of about 5,000 sq. miles. (Map 93 B, E and F).

Nyaungho Stream.—Thaledan Forest Reserve. Said to have possibilities 28 miles from Padaung or 40 from the Irrawaddy west bank, opposite Prome. Discharge not great in the hot weather, but a drop of 1,000 feet or more available.

Pang River.—Tributary of Salween, Southern Shan States. In about 6 miles, at a point 2 miles south of the Taungyi-Kengtung road, there is a fall of some 600 feet in a series of cascades. The stream is of considerable volume. (Map 93 H).

Panlaung River.—Tributary of Myitngc, above Myittha, Kyaukse, is said to be well worth prospecting, as there is a natural reservoir site of some 5 acres extent ; the rock however is mostly limestone, and fissured. Discharges of 400 cusecs and a 900-foot fall were mentioned. Position not identified, but probably good for 5,000 e. h. p. or more. It is believed to have been surveyed already either by Government or the Burma Railways, Limited. The catchment cannot be traced on the Atlas sheets, but includes that of the Zawgyi (q. v.) and is probably over 4,000 sq. miles at Kyaukse. Rainfall 30 to 40 inches. Discharges have been taken from 1909 onwards. The average flow between December and May varied fairly evenly between 1,100 and 400 cusecs. A flow of 500 cusecs can generally be depended upon. (Map 93 C).

Panlang River.—Tributary of Sittang ; also said to be worth examination. It is apparently near the previous entry, but the site has not been identified as yet. (Map 93 C ?).

Papun-Dagwin road.—Near Yedagon hill stream has a discharge of about 20 cusecs in February, and may have a site giving 1,000 feet head.

Pathechaung River.—Near Toungoo. May have a little power, sufficient for local needs (200 e. h. p. ?) But there are no reservoir sites and dry weather discharge is small. The river however is constantly mentioned as worth investigation. Thandaung beyond here has a rainfall of 200 to 250 inches, between May and November, but practically none in other months, and the catchment is quite small. (Map 94 A 12).

Paungdaw Chaung.—See Tavoy.

Payagale Ch. Pegu Division. Minimum discharge at mile 12-6 was ½ cusec on 3rd April 1919.

Pin River.—Tributary of Irrawaddy, flowing from Popa Mount, an old and isolated volcano (4,980 feet) seen from the Irrawaddy from Pakokko to Yenangyaung. The catchment area at Magyigon is about 40 sq. miles only ; elevation here unknown. There are numerous springs on the hill side which it is believed could be collected to give a good discharge at a fair altitude above the flat plain. Rainfall 30 to 50 inches of which 96% falls between May and November. (Map 84 O 4, 8 ; P 2, 6).

Pinkan River.—This is perhaps the same as the Pin ; it has "a perennial discharge and a good fall 20 miles by cart from the Irrawaddy."

Pyu River.—Toungoo. Said to have possibilities.

Pyinpongyi Ch. Pegu Division. Minimum discharge 0·6 cusec on 3rd April 1919, at mile 18-4.

Salin River.—Tributary of Irrawaddy. This is said to be of no use except for the tributary which runs from Kodakham towards Laungshe, which is worth reconnaissance. There is no definite information, but it is stated to be worth 1,000 e. h. p. Mount Victoria (10,085 feet) appears to feed this and the rainfall is in the 50 to 100 inches zones. The catchment area of the tributary in question is about 400 sq. miles. A discharge taken in the main stream near Minyin village, 20 miles above the headworks of the Myaungmadaw Canal, in the dry season of 1919, showed 4 cusecs only, with an additional ½ cusec from the Mwe. (Map 84 K 4 and L 5).

Saingdin Creek.—Akyab District. There is a mainfall of 47 feet and others making up 66 feet below Buthidaung and 8 miles from the Mayu River, all in a length of 1,000 feet. Minimum discharge about 1,000 cusecs and maximum 100,000.

Salween River.—The Hatgyi Rapids about 100 miles south east of Taungyi and 100 miles north of Moulmein, some 40 miles above entry of the Yunzalin

River, and below the mouth of the Thaungin R., are believed to be capable of great development; the possibility of locking the river and making it navigable for boats for several hundred miles further up was also raised. A fall of 70 to 300 feet is believed to be obtainable (reports are conflicting), and the minimum discharge is stated to be over 1,000 cusecs. Another report says there is a triple fall of 20 feet in 300 feet length, with a discharge generally of a million cusecs —presumably this is in the rains. The flood waters however rise about 90 feet. Lime is obtainable. There is a cart road to Mongnai, and pack transport must be employed beyond May be considered worth at least 6,000 e. h. p., but would be very expensive to develop. The catchment area is enormous and covers the whole gamut of rainfall; and there are said to be more many rapids higher up. Above the mouth of the Yunzalin there are said to be many sites, especially 8 or 10 miles above Kammanaung, which is accessible by boat and elephant. Here a canal a few miles long, which the banks would allow to be constructed, would give a moderate head. (Map 94 G, square not known, but probably unsurveyed).

Sawchaung.—Yaw dist. The gorge 4 miles above Saw and 75 miles from Seikpyu can, it is said, be dammed to a height of 80 or 100 feet. There is a good flow in the dry weather.

Shweli River—Tributary of Irrawaddy. Said to have a discharge of 4,000 cusecs in April, with a drop of 1,000 feet in 5 miles, (highest fall at one spot 34 feet) 20 miles below the large swamp or lake near Selan (R. L. 2,400 feet). The lake land is too richly cultivated and valuable to be dammed. There is granite rock in the district, and a good reservoir site exists higher up the river. May be worth from 300,000 e h.p. upwards. Rainfall 50 to 60 inches, over a catchment at this place of 2,500 or more sq. miles. (Map 93 E 6, 9 and 13.)

The upper reaches below Namkhan and the Kyanktake rapids are also mentioned as well at the Nam Chit falls on a tributary, said to be 300 feet high.

Sin Bo Sin Ma falls; See Tavoy.

Sittang River.—There is said to be a good power site on the head waters (?) of this river north of Pyinmana near Yezin village and near Taungnyo. Further north, 20 miles due east of Yamethin, there is said to be a fall of about 1,200 feet, with a minimum discharge of about 50 cusecs, which can be supplemented by storage with considerable bunds. The possibility of tunnelling through to another catchment was mentioned at this site, in which case the water would be useful for irrigation. The formation is limestone, but high mud banks have been used successfully for storage in olden days. The site is probably worth 5,000 e. h. p. Rainfall 40 to 50 inches nearly all between May and November. Catchment area not determinable from Atlas sheets. (Map 94 A 1, 5; 93 D 3, 4).

The tributaries of this river on R. bank are also said to be worth examination, having good perennial discharges up to 100 cusecs in some cases. (Same maps).

Tabak Hla River.—Where the Lwema joins this stream, 2 miles east of Namlang, there is a rocky gorge with a drop of about 150 feet, a good perennial discharge, and a possible reservoir site. Rainfall and catchment area not known. (Map 92 G 12 ?).

Talaingya Chaung; see Tavoy.

Tandin Falls.—North Arakan. There is an ample discharge, used for timber flotation, and a fall of 60 feet. The passing down of the timber is not a matter of difficulty, and the river is believed well worth examination.

Taping River.—This joins the Nam Ti which runs into the left bank of Irrawaddy near Bhamo. About 31 miles up the river from the junction, near the road suspension bridge, where the catchment area is about 450 or 500 sq. miles, there is believed to be a cold weather discharge of 500 cusecs (minimum not known) and a drop of 500 feet in 5 miles. The site is worth examination, and may be worth 10,000 e. h. p. or more. The Tunhong Gorge beyond Kalechet has also been mentioned. Rainfall not known. (Map 92 H 11, 14; latter unsurveyed).

Taungdwin Chaung.—Mingin, Myittha Division. This is stated to be worth reconnaissance, though somewhat remote. Site not identified.

Tavoy District.—One power site has been developed, see Table 2. It is believed that many more, including good reservoir sites, are to be found; but the country has been little prospected for power. Rainfall 150 to 200 inches of which 96 % falls between May and October. Mr. Raikes reports that gaugings will be taken in the following;

Paungdaw Chaung, which has a fall of 600 feet at one point.
Ban Chaung (130 cusecs, 29th March 1919.)
Kalonta gorge (19 cusecs, 19th April 1919).
Kyankpyu Chaung falls.
Sin Bo Sin Ma falls.
Talaing-Ya Chaung.

No falls have been determined as yet, but the first on the list is said to be the most favourable. (Maps 95 J & K).

Teng River.—*Southern Shan States.* (*Nam Teng* ?). Near the Pang (q. v.). This feeder of the Salween is said to have a large volume and a fall of 365 feet some 2 marches from the Tang falls (Map 93 H ?).

Thaukyegat River. Tributary of Sittang, 11 miles from Toungoo. This river has a very large catchment area and before entering the plains is said to have a large discharge, while falls of about 250 feet in 7 miles can be obtained near here, where the catchment area is over 400 sq. miles. It probably falls very low in the driest seasons. On the northern or main branch a fair reservoir appears possible, holding perhaps 1,000 million cubic feet, from which a short channel would run to the power station. The run-off is said to be fair but not high. Most of the smaller streams have a trickle of water and there are many springs. The southern branch is not likely to be of use unless its discharge can be led round by a channel into the northern branch near the junction. The latter appears good for 6,000 to 12,000 e.h.p. from information received, but further examination is required. Rainfall between 75 and 100 inches, of which 96 % falls between May and October. (Map 94 A 11, 12, 16 ; B 9, 13).

Tonbo River.—Mandalay. Attention has been called to the upper reaches of this stream.

Ye River.—near Pagyi (98° X 15° 20′) has about 150 to 200 inches of rain in the elevated catchment of over 400 sq. miles. (Map 95 I 3, 4).

Yezin Ch., Meiktila Division. Minimum discharge 3·3 cusecs near Yezin on 28th April 1919.

Yetagon Falls.—See Mandalay.

Yunzalin River.—This is said to have a rapid fall of over 3,000 feet to near Papun, but is very inaccessible. Where the road from Papun to Kawluck leaves the river the discharge is said to be about 10,000 cusecs and there is a fall of 1,000 feet in 3 or 4 miles. This site is accessible by elephant from Papun and appears very promising. There are others lower down also.

Zamayi River.—Pegu District. There is a waterfall in forest compartment 91 and the river is believed worth prospecting.

Zami River, running to Moulmein. The higher reaches are said to merit investigation as power may be required for pulping work, already proposed there. (Site not identified).

Zawgyi River.—Tributary of Panlaung and Myitnge There is a small waterfall of about 10 feet some 4 miles north-east of Lawk Sawk, showing a good discharge in April, which is fairly maintained. There are said to be many other falls, but little is known. A possible site was also mentioned near Myitson, about 20 miles from Kyaukse. From the hills to the plains there is a fall of some 4,000 feet in 20 miles. The water of this river is said to be exceptionally fine for crops. Rainfall probably between 30 and 40 inches. The catchment above Kyaukse is about 2,500 sq. miles. Gaugings have been taken by the Irrigation Department from 1900 onwards, but until 1909 the low readings were unreliable. From 1910 to 1918 the average flow between December and April varied between 515 and 2,200 cusecs with a mean of about 900. Very heavy floods have occasionally occurred. The drop of the bed is generally said to be quite gradual. (Map 93 C 15,16).

Zingyaik River.—Thaton district. The river is dry for many months, but the waterfall is believed to be worth investigation in case there are reservoir sites above. This is a mining and also a salt district, and power is wanted.

APPENDIX X.

List of Sites in the Central Provinces and Berar.

Aran River.—At Masni, in Magrul Taluk, there is said to be a good site for impounding 5,000 million cubic feet of water with a 90-foot bund 2,600 feet long, having 330 sq. miles of catchment. The submerged land is forest waste land mostly. There is " a good site for utilizing the water with a high fall," which is very indefinite as the layered map shows that the whole district indicated lies between 1,000 and 1,500 feet, so that not more than a 200 foot fall (low medium) is likely. The catchment area at Sangri, probably below the site referred to, is about 300 sq. miles. Investigation is required. Rainfall 30 to 35 inches, mostly concentrated in 5 months, and 85 % between June and September. (Map 55 H 7,11).

Baihar Plateau, Balaghat.—A reconnaissance was made in the hot weather of 1919 and none of the streams had more than a trickle, though villagers stated that the flow continued through the cold weather. Some of the streams appear in the list.

Ban River.—Tributary of Purna, near Wari on the border of the Jalgaon and Akot Taluks. This flows from the Gawilgarh hills, Satpura range, and is said to have a vertical fall of 60 to 70 feet which can be increased. The catchment area is 130 sq miles, to the west of Narnalla. The stream is " practically " perennial and reservoir sites are said to exist. The rainfall, averaging about 30 inches, is said to be good in these hills even in a year when the monsoon fails in the plains below, but it falls to the extent of about 90 % in the 5 months June to October, and 85!% in June to September, so very large storage would be required especially with a view to the necessary carry-over for bad years. (Map 55 C 12,16.)

Bearma River.—Tributary of Ken. A favourable reservoir site with a catchment area of 4,126 sq. miles is reported at Khumergar, Damoh, below the junction with the Sunai (Sonar ?) where a flood discharge of 235,000 cusecs has been recorded. The site has not been identified at present. Rainfall about 45 inches, of which 43 inches fall in the monsoon between June and September. (Map 55 M.)

Bina River.—Near Rahatgarh (Saugor). The catchment area is 500 sq. miles and the slope is said to be fairly rapid ; about 50 feet a mile (?). Reservoir sites have been located above and below here, and are worth investigation. Rainfall about 40 inches, of which 93 % falls between June and September. Estimated by Mr. Batchelor to be worth some 5,000 e.h.p. or more at each of two sites ; but this requires further examination. (Map 55 I 5,6).

Chandra Bhaga.—Close to the Sarpin (q. v.) and the same remarks apply. (Map 55 G 7,11.)

Chargad River.—Tributary of Wardha. A large reservoir could, it is said, be constructed at Udkheir, 9 miles south-west of Morsi, with a catchment area of about 80 sq. miles. Rainfall 35 to 40 inches, nearly all in June to September. No information as to falls. (Map 55 G 15,16).

Chikalda Plateau.—(Melghat). Mr. Batchelor believes that some 2,000 e. h. p can be obtained here from a reservoir commanding a head of 1,800 feet. The site should be examined further. Catchment not specified. Rainfall 35 to 60 inches ; mean at Chikalda itself 67 inches of which 60 inches fall between June and September. (Map 55 G 7.)

Chornai River. - Uprora (Bilaspur). There is said to be a reservoir site with a catchment of 150 sq. miles, and some perennial flow, and a fall of 100 feet is indicated. Estimated by Mr. Batchelor to be worth 8,000 e. h. p. but has not been examined as yet. Rainfall 60 inches, of which 82 % falls between June and September.—(Map 64 J 10.)

Darekasa Waterfall.—Gondia Tehsil. Situated in hilly country near the station of that name on the main line of the Bengal Nagpur Railway. It dries up by the end of the cold weather, so will be useless unless storage can be found. (Map 64 C 11 or 12).

Deo River.—Balaghat district. This rises on the Baihar plateau and flows [illegible]

where the catchment is 120 sq. miles or more. Being near the Nahara and Uskal rivers the conditions are likely to be similar. (Map 64 C 5,6,9.)

Erai River.—Tributary of Wardha, 12 miles north of Chanda. Reservoir sites are indicated, without details. The area does not look particularly promising, though the catchment is about 300 sq. miles, and the rainfall 40 to 50 inches between June and September. There is a known fall of 20 feet on the Mul hills. (Map 55 P. 4, 8.)

Ghisari River.—Near Dhansura, is stated to have a waterfall of several hundred feet, though the stream dwindles down to a few cusecs in the hot weather. Reservoir sites may however be found. (Site not identified).

Hasdo River,—where it leaves the hills above Chhuri and Korba Reservoir sites suggested ; no details, but there is apparently a rapid fall where the plains are entered. The catchment area is about 2,800 sq. miles at Garaghat, where the 1,000 foot contour crosses, and the rainfall averages 60 inches of which 80 % falls between June and September. (Map 64 J 9, 10.)

Indrawati River.—Chatisgarh State. There is a waterfall of 90 to 100 feet at Chitrakot, and the flow is always substantial. In May 1906 760 cusecs were gauged. The rainfall over the large catchment of about 4,500 sq. miles at the falls is 60 to 75 inches, mostly falling between June and September. On the 29th May, 1919, the discharge was 443 cusecs. There is a possibility of constructing a very large reservoir immediately up stream of the fall, where the country is very flat. Reconnaissance indicated that this might carry 50,000 million cubic feet with a dam of reasonable cost, but the land acquisition would be expensive as much of the area is cultivated. The site appears worth 4,000 e.h.p. *without* storage and perhaps 12,000 to 15,000 e.h p. if the storage turns out feasible to the extent named. It is worth full investigation. (Map 65 E 12,16.)

Kanhan River.—An irrigation scheme was prepared involving a reservoir on this river (which the Pench joins higher up) a few miles north of Nagpur, but it fell through. The site may be worth reconsideration for power purposes in combination with irrigation from the tail waters. No details are at present known, except that the site is near the junction with the Waingunga, above the village of Ambhora, and 8 miles south of Bhandara, where any large fall is unlikely. Rainfall over catchment 35 to 40 inches between June and September. (Map 55 O 12.) The catchment at the 2,000 foot contour is 178 sq. miles, increased, before the junction with the Pench, to about 1,200 sq. miles. Four other points on this river between Khapa and the above were also referred to. (Map 55 K 15 ; O 3,8).

Madu River.—Tributary of Wardha. It is stated that reservoirs (of unspecified size) can be constructed north of Destara, Morsi Taluq, having a catchment of 204 sq. miles, but no information is given as to falls. Site not identified but probably on map 55 G 15. Rainfall about 35 inches, mostly in June to September.

Melghat Area.—The possibilities are said to be promising in the Melghat area, where there would be a demand for power from the Tapti and Sipri Rivers and smaller streams mentioned in this list. The rainfall is from 35 to 40 inches up to 60 on the Gawilgarh Hills near Chikalda (q. v.), which fall rapidly from over 3,000 feet to about 1,500 feet. The McKenzie falls are said to be several hundred feet high with a perennial flow ; but the site has not been identified.

Mhas River.—A site is named between Waigaon and Hingna, Nelgaon, Buldana, for a small tank of 10 million cubic feet, which is unlikely to be of much use over 9 dry months. It is stated however that the Mun and Panigunga rivers could also be diverted into this reservoir, thus increasing the catchment from 90 to 450 miles, with a rainfall of about 30 inches concentrated in 5 months, and almost in 3 months. The latter streams are "practically perennial." (Map 55 D, square not identified yet).

Moga River. 12 miles north-east of Ellichpur. It is stated that a reservoir draining 88 square miles may be constructed north of Pala, with "a number of falls *higher up.*" This reservoir is presumably intended to impound the [illegible], as it is useless for power ; but without storage there will probably [illegible] for many months. (Map 55-G 11).

Munyari (?) north-west of Bilaspur. Information was received of an abandoned irrigation reservoir scheme here, which it was stated might be worth examination for power purposes. (Map 64-J 7 ?).

Murna or Morna River. At Shaikla, 16 miles south of Akola, a reservoir of 80 square miles can, it is said, be constructed by a bund one mile long and 70 feet high. Whether a rainfall averaging about 30 inches over a catchment area of about 110 square miles (taken from the millionth map only) will fill this reservoir and give nearly 7 months' dry weather supply is a matter for further consideration. The river is "practically perennial." (Map. 55-D 15 and H 3).

Nahara River.—Balaghat district. This comes down from the Ghat a few miles east of Charegaon Station, ending in a considerable waterfall (Jhang Gogra fall). A reservoir site was found near the village of Sale, but the 4 inch Forest maps may serve to locate others, as the upper reaches are not well known. With a 5 mile channel from the site mentioned a fall of some 500 feet would be obtainable. The catchment area is about 120 square miles there and the average yield about 12,000 million cubic feet. Rainfall 60 inches, mostly in June to September. The site, allowing for a large carry-over for bad years, is reckoned worth some 9,000 e. h. p. (Map 64-B 4, 8 and C 1).

Nawegaon Tank.—This is situated in a basin surrounded by hills in Sakoli Tehsil, Bhandara District, with a catchment of 23 square miles, and a water spread of 5 square miles. In June 1919 the discharge was about 5 cusecs. It is not known what fall is available. The site is a mile from Dewalgaon on the Gondia-Nagbhir branch of the Bengal Nagpur Railway. (Map 64 D 1).

Nerbudda River.—Discharges have been taken during the dry season of 1919, but have not come to hand as yet. The river is known to have possibilities but they have been little examined except at the falls at Marble Rocks near Jubbulpore; and no details of this scheme have come in. It was proposed however to manufacture cyanamide. (Map 55 M 16).

Ibid.—The Dharighat fall in Nimar District has also been put forward. The actual fall is 50 feet, but it can probably be increased to 100 feet or more, and the flow is "large". This site is in dense forest, 24 miles by road from Bir station on the Great Indian Peninsula Railway. The rock is hard Vindyan sandstone. (Map 55 B 7).

Ibid.—The Baroda Darbar also calls attention to the Khodiar Mati falls on the Nerbudda in Dhari Taluka, which may be the same as above: also to the Mokhadi falls, which have not been identified.

Pench River.—A definite site is indicated near Bhiwagarh, 22 miles directly north of Nagpur, where the catchment is about 1,700 square miles. Other sites are indicated on the river, which requires further examination. The catchment area is 527 square miles where the 2,000 foot contour is met. The discharge between Seoni and Chhindwara was practically *nil* in May 1919. (Map 55 O; 1, 2, 3, 4, 5, 8).

Mr. Batchelor's Silewani Ghat scheme also brings in this river.

Penganga River.—There is a fall on this perennial river, which forms the boundary between Yeotmal District and Hyderabad, known locally as the Susar Kund. No details are available. The site has not been identified, but is on Map 56, E or I.

Purna River.—The remarks on the Moga River apply here. The falls are *above* the reservoir.

Sarpin River.—At Wajar, 8 miles north of Ellichpur, Amraoti. A fall of 2,000 feet is said to exist in 10 miles; the catchment area however is given as 44 square miles only, and "with impounding reservoirs along the course of the stream very cheap energy can be obtained." The conditions appear to be the very reverse, but the site should be examined. Rainfall about 35 inches, mostly falling in 4 months. (Map 55 G 7, 11).

Shahnur River.—West of Ellichpur (Amraoti). A reservoir site is indicated by Mr. Batchelor between Tekra and Ambaparti, with a catchment of 12 square miles and a possible fall of 600 feet. A further site between Raipur and Moragarh has been mentioned. Rainfall about 35 inches, mostly between June and September. (Map 55-G 7 and 8).

Silewani Ghat. Mr. H. Batchelor, I.C.S. [illegible]

present Report—dealing with the Chhindwara area. There is, in the pamphlets issued, a great volume of assumption and no very clear description of the schemes themselves but at the same time attention has been drawn to an area which is well worth technical investigation. Mr. Batchelor's estimate of an available 70,000 kW or say 94,000 e.h.p. must be taken with great reserve. One site of those mentioned was visited by Mr. Barlow who recorded his opinion, as follows:—

"The proposals for Umra Nala tanks are wrong; the catchment area is too small. Run-off will be poor, rainfall is not high, area flooded is A 1 land but probably cheap and the line of the canal from the reservoir to the edge of the ghat runs through undulating country where rock is near the surface. The site is certainly near the ghat, and the drop in the ghat is good; but it is not sudden and a long pipe would be necessary. The Nala is joined by another larger Nala a little way on the far side of the *pacca* road and the Railway, and a proper reconnaissance is required to find a suitable storage site near the Ghats, with a good drop. Nagpur already requires 5,000 h. p. and this will increase if power can be provided cheaply. The project (*i.e.* the whole series of projects) is therefore one of the first that should be investigated. "Again, Mr. Barlow notes "His ideas are good but his figures are unreliable and useless. Some of his proposals are undoubtedly worth further consideration, but no reliance must be placed on his details." Examination of the maps of the district shows that possible reservoir sites certainly exist; the question of their employment and cost should be further examined.

Briefly the following is an outline of the chain of projects, which can only with difficulty be traced from the printed account. The main power station, one mile North of Khapa, elevation 1,200 feet, on the Kanhan River (Map 55 K 13, S. W. corner), is to be supplied by a long pipe line down the Ghat from Silewani Tola at 2,150 feet. The system is to be fed by a canal from a service reservoir on the Umra Nala, estimated to have a draw-off capacity of 600 million cubic feet, of which the dam is to be one mile North-East of Mau. A second dam immediately above this, up to the 2,200 feet contour, and an Upper Umra Nala reservoir one mile North-East of Palakher feed this. Yet another dam for the Chin Nala reservoir is placed one mile West of Umaria Dalel running up to the 2,200 feet contour, to feed the service reservoir by a canal. On the head of 950 feet gross Mr. Batchelor estimated this group to be capable of giving 1,400 e. h. p. at the high cost of Rs. 1,500 per e. h. p. (say Rs. 2,000 per k. w.), on his assumption of a 30 per cent load factor.

Further North is the Rohna reservoir site, one mile North of Rohna on Map 55 J 16, running up to 2,250 feet, and estimated to contain 3,000 million cubic feet. Mr. Batchelor proposes to canal this water to the Chin Nala reservoir, a distance of 16 miles, so after allowing for the slope of the canal a good deal of this water would not be of any use.

North of this again, a nine mile canal (including a three mile tunnel) would discharge the waters of the proposed Upper Pench reservoir *viâ* the Kulebehra Nala into the Royna reservoir. The site of the dam across the Pench River is two miles North of Chhinda, at the top of Map 55 J 16, and it is proposed to carry it up to R. L. 2,450 feet. The site is certainly very favourable on the map, and a short dam is estimated by Mr. Batchelor to impound 12,000 million cubic feet. Minor power stations are also proposed below this lake.

Further dams are proposed on the Pench River one mile West of Palatwara up to 2,250 feet (Map 55 J 16), and on the Gunor one mile North-East of Thesagora on the same Map up to 2,350 feet. These, however, though possibly of use for irrigation, would appear to be too low down for feeding the power system.

At first sight it would seem that if the Upper Pench site is good, and if its waters can be led at any reasonable cost to the edge of the Ghat, it would be better to concentrate on this and to omit all the smaller reservoirs except the regulating one, and all the minor power stations.

If Mr. Batchelor's estimates are at all near the truth, the cost of the Upper Pench reservoir and the regulating reservoirs at the Umra Nala, together with the necessary canals, would be in the region of 110 lakhs. The

storage, if correct, would on a 900 feet net head give some 22,500 kilowatt years, allowing of a plant of 45,000 kilowatts on a 50 per cent load factor, making a cost of some Rs. 250 per kilowatt for the hydraulic works, exclusive of the pipe line and power house. This, if attainable, would be a reasonable figure.

Son River.—North east of Langi, above Bijagarh. Indicated, but without details. Reconnaissance required. (Map 64-C 9, 10, 13, 14).

Tan River.—Pendra, Bilaspur. A reservoir site is indicated at an elevation of about 2,000 feet, with a rapid fall of 700 feet, where this river comes into the plains near Marai. The normal rainfall is 50 to 60 inches, concentrated into the months of June to September. The catchment area however is very small, some 15 square miles, and large carry-over would be required. The site may be worth 1,000 e.h.p. or more. (Map 64 F 9, 10, 13, 14).

Tapti River.—This rises in the Aravalli Hills, which it leaves some 25 miles east of Burhampur. The catchment area above here is about 2,000 sq. miles, with a rainfall of about 40 inches and there is a perennial flow. A site for a dam has been indicated but is apparently situated where there would be little or no further fall. The river at Betul was found dry early in June 1919, though it runs until the beginning of the hot weather. A possible site for storage was found, with a series of drops aggregating 100 feet. As the area is favourable further reconnaissance is desirable. (Map 55 C-7, 11, 14, and G 2).

Tawa River.—Said to be worth investigating where it enters the plains at Bagra, near Itarsi, Great Indian Peninsula Railway. The layered atlas sheets indicate that at the junction with the Denwa tributary there is a narrow neck between spurs. The rainfall is 50 to 70 inches in the upper parts of the catchment, mostly falling in June to September. (Map 55, F. 14).

Umra Nala; see Silewani Ghat *supra*. (Map 55 K 13).

Uskal River.—Balaghat District. This is stated to be perennial and to be capable of a fall of 1,000 feet or more, near the village of Udwa, Balaghat junction, presumably below the junction with the Nahara (q. v.) but not so far located on the 1 inch map. The locality has greatly mineral possibilities, and power is certainly likely to be wanted in future. It is stated that some 4,000 continuous e. h. p. at least can be got from the site, and by further raising the proposed dam 17 feet the capacity of the tank can be doubled. A local report on the site exists, and it is still under investigation. The catchment area above the junction with the Nahara is about 130 sq. miles. Rainfall normal about 60 inches during the June to September monsoon. (Map 64 B 4, 8).

Waingunga River.—Small falls are indicated, but no details of any value as yet. Judging from its tributaries the river should be worth further reconnaissance. The catchment area above the 2,000 foot contour is 275 sq. miles; at the 1,000-foot contour it is about 1,800 sq. miles. Rainfall 50 to 60 inches, mostly between June and September. See entry under the Kanhan River also. (Map 64 B. 3, 4 and C. 1).

Wardha River.—Small falls are said to exist near Pulgaon and Mr. Batchelor believes that 1,000 e. h. p. is available. No details are available, but the catchment area is over 2,000 miles here. Rainfall 35 to 40 inches, mostly between June and September. (Map 55 L. 5 and 6).

Canal Falls, Central Provinces.

The Chief Engineer, Irrigation Branch, considers that there is good scope for utilizing the canal falls for pumping to uncommanded areas, especially from the Mahanadi canal, where large areas of well drained *bhata* soils lie out of command. This soil is particularly suitable for growing long-stapled cotton, as recommended by the Cotton Committee. The canal falls are not likely to be of any use for general purposes as they only run a comparatively small number of days in the year. Most of the irrigation is done during the Kharif; rabi irrigation is purely subsidiary. There are 62 canal falls, running from 90 to 120 days.

APPENDIX XI.

List of Sites in Madras.

Aliyar River.—Anamalai Hills (q. v.). There is said to be 2,000 feet of fall, of which 500 feet could easily be utilized, in this river some 40 miles from Coimbatore and 16 from Pollachi. The discharge is believed to vary from about 800 down to 6 cusecs. Further observations will be made. The catchment area is small, but the rainfall varies from 40 to 75 inches over it, well distributed from April to November. Probably worth 2,000 e. h. p. or more. (Map 58 B. 15 and F. 3).

Anamalai Hills.—Messrs. Siemens are interested in the Kayanapardal Falls, Sholujar (Suruli ?) River, near Coimbatore. No details are available. See also Aliyar River. (Map 58 B. and F.).

Bhavani River.—The falls near Thondai, 13 miles above Metupalliam, and 22 miles from Coimbatore are said to be about 50 feet. The catchment above them is about 400 sq. miles. The discharge is believed to vary from over 3,000 down to 40 cusecs. Observations are being made of the dry weather discharge in 1919. The rainfall contours probably give too high a precipitation for this catchment, but there are no stations in it. It may be anywhere between 20 and 75 inches. December to March are dry months. (Map 58 A. 16).

Ibid.—Malabar District. A fall of 2,500 feet in 3 miles is shown on the upper Bhavani, 45 miles from Coimbatore and 21 from Ootacamund. A water level recorder will be installed as gauging cannot be undertaken at this out of the way spot. The catchment area must be very small here, but the above distances meet outside the Bhavani catchment altogether. (Map 58 A. 12).

Cauvery River.—Apart from the existing development (see Table 1) there have been proposals for utilizing the Goat's Leap Fall, the Mekadatu Falls (q. v.), and the Hogenkal Falls (q. v.). The Goat's Leap Fall is 26 miles below Sivasamundram, and no details are available.

Chalakudi River.—Cochin. This has been investigated by Mr. Forbes, Chief Electrical Engineer, Mysore. He states that the minimum flow is 50 cusecs and storage of 1,000 million cubic feet is proposed. The site is estimated to be good for 25,000 e. h. p. on 577 feet head. (Map 58 B. 11).

Chandravauki River.—Guntur District. The Ettipotata waterfall is near Macherla, and 16 miles from Gurzala. No details are known and the site has not been identified as yet, but the river is presumably one of those flowing into the Kistna from the north. These all appear from the layered map to pass through fairly narrow gorges within 10 miles of the big river, and reservoir sites may exist above. The Superintending Engineer is examining the site and will take dry weather discharges. Rainfall about 30 inches, of which 92% falls between June and November. Catchment area not determined. (Map 56 P.).

Cochin State.—There are believed to be possibilities of considerable magnitude in this State, but no details have been made public. Some 24,000 e. h. p. can, it is understood, be developed, presumably from the Chalakudi River (q. v.).

Coonoor and Karteri Rivers.—When the Coonoor-Ootacamund section of this hill railway was being built in 1905, the Electrical Adviser to the Government of India drew up a project, at the instance of the Railway Board, for its electrification. The site chosen for power development was on these two rivers, near Runymede, some 3 miles from Coonoor and 12 from Ootacamund. The project was limited to what was then required, and details are given in Table 4. A far greater head than the 1,000 feet proposed, probably up to 3,500 feet, could however be obtained. The minimum discharge in 1905 was 4·3 cusecs for the Coonoor branch and 12 cusecs for the combined streams. Large storage is possible. Further investigation is proceeding. The Karteri River is already employed in its upper reaches for the Government Cordite Factory ; see Table 2. The rainfall over the catchment area of some 60 or 70 sq. miles is particularly well distributed. It averages about 60 inches, catching both the south-west and north-east monsoons, and from April to

November the monthly averages are reasonably constant. The worst months are January to March, but they receive about 10 per cent. of the total in average years, or some 2 inches per month. (Map 58 A. 15).

Gundar Valley.—Near Kodaikanal. Attention has been drawn to this valley. The catchment area is very small, about 8 square miles, but the rainfall of 60 inches is well distributed throughout the whole year; even January and February each receive an average of nearly 2 inches. The perennial flow is good and a fall of about 1,000 feet is said to exist. There are also said to be good reservoir sites. (Map 58 F. 7, 8, 11, 12).

Hogenkal Falls.—Cauvery River, Salem and Coimbatore. The utilization of these falls (also called Smoking Rocks Falls) on the River Cauvery, 66 miles above Erode, has long been discussed especially in connection with the Salem iron ore district 40 miles distant, where electrical reduction has been contemplated. Some survey work has been done at the dam site, where the rock is said to be a brittle granite. A head of 46 to 85 feet is available, according to whether Metur reservoir is or is not constructed. The flow of water depends on unsettled irrigation projects, but is likely to be of the order of 550 cusecs minimum, so that some 2,500 e. h. p. at least is available at the site. The maximum flow is about 250,000 cusecs. The power available would be increased to well over 3,500 e. h. p. if certain other projects materialize. The cost has been estimated as about Rs. 570 per h. p. installed or Rs. 760 per kW. The water rights of the river are somewhat complicated as between Madras and Mysore. A survey has been made and cross-sections of the river taken above and below the falls. A site for a low dam is being investigated. (Map 57 H. 12 or 58 E. 9).

Karteri River.—See Coonoor River; also table 2 "Cordite Factory."

Kolakambe water fall.—Nilgiris. This is a neighbour of the Karteri River and has a drop of about 600 feet, but by means of a short tunnel a fall of 1,000 feet could be obtained. The waters of the Karteri could probably be diverted into this stream below the existing power house of the Government Cordite Factory (table 1). The minimum flow is believed to be about 10 cusecs. With a short high dam it is believed that 3,000 e. h. p. might be obtained. (Map 58 A. 11, 12).

Kundah River.—A project for utilizing this most promising river in the Nilgiris, 9 miles from Ootacamund, was sketched out by the Hon'ble Mr. Murray, then Chief Engineer, P. W. D, Madras. It appears well worth further investigation. The catchment area at the Kundah bridge is 65 sq. miles and the minimum discharge recorded in 1918 was 31 cusecs, but by comparison with neighbouring catchment it is believed that the true minimum in a very dry year, such as 1914, would be about 20 cusecs; gaugings are proceeding. There are two good reservoir sites, one in the main river a mile above the junction with the Emerald Valley stream and one in that valley itself, where the minimum flow is estimated to be 4½ cusecs. This latter site has not been fully examined. The mean rainfall is about 80 inches and is extremely well distributed; a run-off of 60 inches is estimated from known data, giving some 1,600 million cubic feet available for storage in the Kundah river site, with an estimated minimum flow of 5·6 cusecs at that point. The site allows some 828 million cubic feet to be stored with a dam of 120 feet. The fall in the neighbourhood is about 3,000 feet of which 2,000 feet are in 2 miles, but it has not been determined whether this could be utilized. The scheme however appears likely to yield some 20,000 e.h.p. or more and is worth thorough investigation. The minimum flow in 1917 was 30½ cusecs and in 1919 24 cusecs; no readings were taken in 1918. (Map 58 A 11, 12.)

Malabar District.—Said to have great possibilities, with high rainfall and jungle products, such as bamboo for pulp, which may require power. The average rainfall is about 120 inches and is fairly well distributed over April to November, though 70 per cent. of the total fall occurs during the 3 months June to August.

Machkand or Sileru River.—This appears from the Atlas sheets and the ¼ inch maps to have great possibilities if levels are favourable, but practically none are given. A fall of 540 feet with a discharge of 104 cusecs in the driest part of May, 191[illegible] has since been reported. The site has not been identified

Mekadatu Rapids. Cauvery River.—These are 28 miles above Hogenkal falls (q.v.) and 21 miles below Sivasamundram (see Table 1, Cauvery falls). The distance to Salem is 67 miles. The flow is the same as that at Hogenkal falls and the drop is 175 feet. The frontier between British and Mysorean territory runs down the centre of the river, and negotiations are proceeding between Madras and Mysore as to the utilization of the fall. An estimate has been framed by the Chief Electrical Engineer, Mysore. At least 8,500 e.h.p. is continuously available on the 550 cusec minimum. (Map 57, H 8 or 12.)

Nurpurya River.—Nilgiris. This is stated to be worth examination at Cherambadi Village, in the Wynaad, reached *viâ* Gudalur, Devala and Pandalur. The Glenrock Tea Estate is near by. (Map 58 A 7).

Periyar Project.—The history of the proposal to utilize the water of the Great Periyar Lake in Travancore for power purposes would fill a volume and stretch back a generation, and it is sufficient to say that negotiations are still proceeding between Government and Mr. Garrett, a retired Chief Engineer of the Madras Irrigation Department. There is an available fall of about 1,000 feet and a minimum supply of 250 cusecs for 240 consecutive days has been the basis of negotiation. This is equivalent to some 54,000 e.h.p. (Table 4). There is little doubt that, as a rule, power of this order could be generated for a longer period in most years; but as matters stand, it cannot be guaranteed. The construction of a supplementary reservoir above the lake, in the Cardamon Hills, Travancore, would enable 150 cusecs to be given continuously, and this might indirectly benefit industrial India (including this progressive State) greatly, as the manufacture of fertilizers is proposed. For reasons which cannot be discussed here the supplementary project is held up, but it is highly important that a settlement should be arrived at. A suggestion may, however, be hazarded as to the project as it stands. The draw-off level is fixed by the location of the tunnel which carries the supply through the water-shed; and the lowering of this tunnel a few feet, so as to increase the possible draw-off, would be a costly matter. If, however, a power plant is put up, utilizing the full 1,000 feet head, it would be a comparatively simple matter to utilize a fraction of the power to pump additional water from the lake, below the present draw-off to the tunnel level, a suitable intake chamber being constructed for the purpose. Thus, if the total lift were 5 feet not much more than one two-hundredth of the power would be sacrificed and a much longer working period would be possible. (Map 58, G. 2, 3.)

Pykara River.—A project to utilize this river (See Table 4) for the supply of the Ootacamund District (15 miles from the town) was drawn up by Mr. H. P. Gibbs and has been the subject of negotiations between him and the Government of Madras. The lowest gauging recorded on the river at the power site was 9½ cusecs in 1914; gaugings have been resumed since and have varied from 15¼ cusecs minimum in 1917 to 19 minimum in 1918. Two falls aggregating practically 900 feet could be combined, but it is believed that 3,000 feet could be obtained by tunnelling through the watershed to the catchment on the north. A storage site exists above the upper fall, but the capacity is not known. It is believed that the scheme is good for at least 2,000 e h p. or more continuously. The mean rainfall is about 76 inches and both monsoons affect the catchment area to some extent; from January to March however the average precipitation is very low. The catchment area has not yet been determined. (Map 58, A 10.)

Sandy Nullah.—Five miles from Ootacamund. This small scheme with a minimum flow of 1 cusec and a fall of 1,000 feet is being investigated for local employment; see Table 4.

Sileru River: see Machkand.

Silent Valley.—The District Forest Officer, South Malabar, states that a short dam 200 feet high would form a reservoir 6 miles long, though not of great width. The position is 1½ miles up stream (name of river not given) from the point where the river crosses the forest boundary. The rainfall is at least 150 inches and the catchment "large." The fall available is not stated, but there is a "considerable drop" into the plains of Malabar, South of Mannaghat. The dry season lasts from the middle of January till the end of April. (Map 58 A 8).

Singamputti Scheme.—Madura District. This was mentioned, but the site has not been identified.

Siramalai Hills.—Mr. H. Perry has suggested that a power scheme for the Madura District can be formulated in these hills, situated 20 miles from the town in the Ammayanayakanur Zemindari. The rainfall map shows a mean between 30 and 35 inches in the surrounding plains, but the hills probably receive more; Mr. Perry's estimate, obtained from a Planter, is 65 inches; but there are no true records in the hills. The catchment area proposed is only 8 square miles, and a considerable number of artificial reservoirs is proposed; the fall available is stated to be 1,500 feet. The power available is estimated by Mr. Perry at "6,500 h. p. *per minute,*" and the words italicized show that caution must be exercised in accepting his conclusions; see Appendix IV. The project requires to be examined by an expert, and may prove less expensive and more reliable than would appear at first sight; various enquiries were made as to its practicability by persons interested in local industries. (Map 58 J 4).

Siruvani River.—Tributary of Bhavani. A project, first mooted so long ago as 1879, has recently been investigated for utilizing this stream for combined water supply and power to Coimbatore, which is 25 miles distant. By damming up the valley so as to form a lake, and piercing the ridge with a tunnel, there would be an available fall of some 1,200 or 1,300 feet; some of the tail water would then be piped to the town for water supply. The minimum flow of the stream is small ($4\frac{1}{2}$ cusecs) as the catchment area is only $6\frac{3}{4}$ square miles, but as it receives both the south-east and north-west monsoons, with an annual rainfall of 75 inches or more, it is merely a question of storage. From December to March there is not much rain. The proposed dam would hold up from 280 to 450 million cubic feet according to height, from 120 to 140 feet; and with the fairly frequent rainfall replenishment it is believed that the site is good for about 2,500 to 5,000 e. h. p. continuously. (Table 5). The tail waters can be used for irrigation. Investigation is still proceeding. It is understood however that expert geological opinion condemns the dam foundation, and if this is so the scheme cannot materialize. The neighbouring Kundah River scheme is more promising, though the Siruvani can still be used for water supply. (Map 58 A 12, 16).

Suruli River.—See Anamalai Hills.

Tambrapani River.—The Paponasam falls, 22 miles from Tinnevelly and 54 from Tuticorin, are 250 feet high. The river is already utilized by Messrs. Harvey Brothers for their mills at Ambasamundram. Gaugings have been made in connection with an irrigation reservoir above the falls and work will proceed. (Map 58 H 6, partly unsurveyed).

Canal Falls, Madras.

The following falls, of which the exact positions are recorded but not printed here, are capable of utilization for power on a small scale. Nos. 1 to 12 are on Map 94 and the rest on Map 95. It is proposed to use No. 17 for pumping from the Kistna River to irrigate 10,000 acres. The remainder are not required either for sub-soil pumping or for pumping to uncommanded areas. The power aggregates about 3,300 e.h.p.

Serial No.	Canal.	Position.	Fall in feet	Minimum flow except at closure.	Working period.
	Godavari Eastern Delta.				
1	Cocanada Canal . .	Medapadu lock weir .	10·0	373	11 months.
2	„ „ .	Tossipudy Lock . .	6·75	268	„
3	„ „ . .	Chintapally Lock . .	8·5	108	„
4	Bank „ . .	Kulla Lock . . .	8·5	101	„
5	Coringa „ . .	Vella Lock . .	8·25	91	„
	Godavari Central Delta.				
6	Gannavaram Canal . .	Gopalpur Lock . .	4·80	425	11 months.
7	„ „ .	Mondepulanka Lock .	5·58	287	„
8	Bank „ . .	Wadapalem Lock . .	5·25	414	„
9	Amalapur „ . .	Palivela Lock . .	4·16	407	„
	Godavari Western Delta.				
10	Bank Canal . . .	Siddhantam Lock .	9 to 12 ft	100	11 months.
	Kistna Eastern Delta.				
11	Ryves Canal . . .	Komatigunta weir . .	6·84	1350	9½ to 10 months
12	Bandar „ . .	Kankipad Lock .	4·25	481	„
13	„ „ . . .	Veeranki Lock . .	10·41	224	„
14	Bantumilli „ . .	Cowtaram Lock . .	5·60	316	„
	Kistna Western Delta.				
15	Bank Canal . .	Kollur Lock . . .	5·54	330	9½ to 10 months
16	Commanur „ . .	Kollimerla Lock .	5·60	324	„
17	Head of Commanur Canal	Duggirala Lock . .	7	200	...

APPENDIX XII.

Sites in North-West Frontier Province.

Indus River.—This is not considered likely to be capable of development, at any rate economic development, in the Himalayan area; the proposed Sukkur barrage (Bombay Presidency) may or may not be able to supply power. It is early to speak of this until the project materializes, but the possibility of high level pumping to canals, should it be required, may be borne in mind.

Kunhar River.—This joins the Jhelum not far from the Abbottabad-Kashmir road and had many rapids with a large perennial flow. As however the district is within easy transmission reach of the Kashmir Darbar's power station at Mohora on the Jhelum (table 2), where much surplus power is already installed, it is unlikely that any other large scheme will be required for the present. (Map 43 F 7).

Sinan River, trib. of Indus.—This flows in from north of Mansehra, and at the time of the Boer War a small plant was erected on one of its tributaries to supply the prisoner's camp. It was subsequently dismantled. It is probable however that sites exist in the main stream, which has not been prospected. (Map 43, F 3).

Canal falls in N. W. F. P.

Upper Swat Canal.—Soon after leaving the headworks this runs through the Malakhand tunnel and then, on exit, down a steep river bed, which is pitched. At Dargai the right and left bank canals take off. The discharge of the canal is 2,200 down to 1,000 cusecs, and the drop available below the tunnel is about 230 feet, giving a minimum power of 20,000 c. h. p. Mr. Sangster, who was in charge of the works, and Mr. Walton, his assistant, read papers on the subject before the Simla Engineering Conference; and Captain (now Lt.-Colonel) Battye proposed the utilization of the falls for the manufacture of nitrates, in a paper read before the Punjab Engineering Congress. The district however is a wild one. Constant power could be obtained by tailing into the river below the power house instead of into the canal as proposed by Mr. Sangster. The canal has to be closed for 10 days every alternate year to provide local irrigation in the rains on the banks lower down the river. Riparian rights necessitate this. Otherwise the canal could probably be run constantly.

Upper Swat Canal.— Branches. By utilizing the existing falls these have considerable power available; there are frequently groups which will permit of 30 to 50 feet drop with a minimum discharge of several hundred cusecs during about 286 days in the year. Unless required for irrigation pumping however there is not likely to be much demand for power.

Lower Swat Canal.—There are no falls suitable for power here, but near the head works power is now generated for the works by dropping the water about 50 feet down into the river area, where there are small canals that require feeding. The site could be utilized later. There is also another small scheme near the tail of one of the distributaries, for developing power for pumping water for a new grass farm. Elsewhere no pumping is required in this district.

Cabul River Canal.—A scheme has been considered for running water from one branch to another, near Peshawar, giving a 50 foot drop.

APPENDIX XIII.

List of Sites, Punjab.

Baspa River, trib. of Sutlej. At Raturing gorge this pours over a series of cataracts below Sangla, with a drop of about 500 feet in half a mile. It is believed to be a good site, though remote. (Map 53 I, 7.)

Beas River.—This has not, so far as is known, been prospected for power. Between its rise at the Rohtang Pass in Kulu and the plains there are however continual rapids, during which the descent amounts to several thousand feet. Whether there is any concentration of falls sufficient to allow of economic development is not known. Several of the larger snow fed tributaries in Kulu, especially the Parbatti and the two rivers flowing in at Largi, have also great potential power; but they are used for extensive timber transport up till the monsoon, so it would perhaps be impossible to divert the water from the stream without interfering with forestry. The catchment area is 5,700 sq. miles and the average rainfall over it is 62·5 inches. The maximun flood at Naushera is 325,000 cusecs and the minimum recorded discharge 2,600. (Map 53 A 1, 5, 9, 13, 14 and B 2).

Chenab River. (Kashmir).—A project has been proposed for utilizing this river at Riasi, where 30,000 e. h. p. can, it is said, be developed. The catchment area is 12,000 sq. miles, of which half is in the exterior Himalayas, and the average rainfall is 41·7 and 28·7 in the exterior and interior divisions. The maximum observed flood carried some 600,000 cusecs and the minimum recorded discharge is 3,884 at Marala. (Map 43 K 16).

Giri River.—The upper reaches of this perennial river were prospected about 1900 for power for Simla, but the Nauti Khad was found preferable. There are probably good sites for power lower down, but they are not recorded. The rainfall is from 50 to 75 inches, and is well distributed except for October to December, which are dry months. Much of the winter rain falls as snow in the upper areas, thus tending to equalize the discharges. The catchment area is about 600 sq. miles at the junction a few miles from Solon. (Map 53 F 6,10).

Haro River, near Hasan Abdul, Attock. Enquiries have been made regarding this river and the Jablat (or Chablat) in the same district, and discharges were asked for. There is said to be a fall of 50 feet and a good perennial discharge. Rainfall 25 to 40 inches. (Map 43 C. 5, 9, 13).

Indus River.—(See also entry under Bombay). The catchment areas above Kalabagh amount to 50,400 sq. miles in the exterior Himalayas and 63,000 in the interior range, with average rainfalls of about 26·6 and 7·6 inches respectively. The maximum recorded flood discharge at Kalabagh is 1,000,000 cusecs and the lowest observed flow 18,870. The bed here is narrow and if a 100 foot dam could be constructed the *minimum* power would be about 170,000 e. h. p. Below the bed widens out greatly, so the flood afflux would be small.

Jablat River.—See Haro River.

Jumna River.—(See also entry under the United Provinces). The catchment area above Tajawala is 4,400 sq. miles with an average rainfall of 73 inches. The maximum recorded flood carried about 273,000 cusecs and the lowest observed flow was 2,195 at that place.

Jhelum River, (Kashmir).—Already partly developed at Mohora (Table 2) but further power can certainly be obtained. The flume line of the existing plant is large enough for 4 times the power now installed. (Map 43 J 4). Captain (now Lieut.-Colonel) Battye, R. E., in a paper read before the Punjab Engineering Congress, 1914, suggested using this river for power at Rasul, at the head of the Lower Jhelum Canal. A flow of 4,500 cusecs and a head of 80 feet were stated to be obtainable, giving 33,000 e. h. p. (See Table 2). The catchment areas in the exterior and interior Himalayas are 7,000 and 8,000 sq. miles respectively, with average rainfalls of 39·5 and 46·2 inches. The maximum flood at Rasul carried about 500,000 cusecs and the minimum recorded discharge is 4,500 cusecs.

...nga River, tributary of Jhelum (Kashmir).—No information but the catchment area is certainly over 2,000 sq. miles at the ... the main river, and it is snow fed. (Map 43 F 11, 14, 15).

Kunhar River, tributary of Jhelum.—No information is available, but the catchment area is about 1,000 sq. miles at the main junction, and the river is snow fed. (Map 13 F 6, 7, 9, 10).

Mogri River.—Rampur Bashahr State. The Chief Wazir of this State believes that a fall of 600 feet or more could be obtained in a mile or two of channel in this river, which is snow fed and has a dry weather discharge sufficient to drive about 10 of the local water mills —or say 30 to 10 cusecs. The stream is probably worth 2000 e.h.p. or more. (Map 53, E 11, 15).

Punch River, tributary of Jhelum, (Kashmir).—This appears to be worth examination near Kotli where the catchment is about 1,400 sq. miles; but no information exists regarding the river. It will be snow fed during at least the early part of the hot weather, as it rises in the Gulmarg snows. (Map 13 G 14, 15).

Ravi River.—This has not been prospected in the hills, but certainly has considerable possibilities. Where the Upper Bari Doab Canal takes off near Madhupur a *gross* fall of 109 feet can be obtained in 4·6 miles; 140 feet in $7\frac{1}{2}$ miles; 175 feet in $9\frac{1}{4}$ miles; and 200 feet in 13 miles. Mr. Milne in a paper read before the Punjab Engineering Congress, 1919, states that the minimum recorded discharge there is 1,300 cusecs, which would give a continuous 12,000 e.h.p. on the smallest and most practicable combination of these many falls. The excess water not required for the canal could be surplussed back to the river. The project has been estimated to cost Rs. 530 per e. h. p. or Rs. 716 per kilowatt installed. See entry in table 5. The normal supply is nearer 5,000 cusecs. A cross-section is available but is not printed. The catchment area of the river is 2,500 sq. miles with an average rainfall of about 93 inches. The maximum flood discharge is about 200,000 cusecs and the minimum recorded flow 1,303 cusecs at Madhupur. (Map 43 P. 11, 14, 15 with 52 D 2).

Sutlej River; Bhakra Dam project.—The proposal to use the great power of the Sutlej where it enters the plains near Kirthpur, north of Rupar, at the head of the Sirhind Canal, is not dependant on, nor does it in any way interfere with, the project for storing some 112,000 million cubic feet of water behind this 395 foot dam. The proposals given in Mr. F. Milne's paper, read before the Punjab Engineering Congress at Lahore in April 1919, involve tunnelling through the spur round which the Sutlej makes a great loop at Oel and Anandpur; a fall of some 430 feet or 330 feet effective can be obtained in this way, and the minimum discharge of 2,700 cusecs (usually not below 4,000) which must in any case be allowed to pass down the river could be utilized to give some 81,000 e. h. p. continuously. The lake would extend above the headworks, but its storage would not be drawn on beyond the minimum flow coming in. The cost is estimated to be Rs. 313 per kilowatt installed. The only differences that the dam project makes in the hydro-electric is that, if the former is built, the tunnel will be under the pressure of a considerable head of water; whereas, if the dam is not built, a diverting weir must be built across the river at the tunnel entrance. It is probably that below the dam also some 10,000 e. h. p. could be obtained if the main scheme is blocked by the fear of interference with irrigation. This site was first suggested by Messrs. Crompton & Co. in the early nineties. The reaches further upstream have doubtless great possibilities, but at a much higher cost. The catchment areas of the river amount to 5,000 and 16,000 sq. miles in the exterior and interior Himalayas with an average rainfall of about 44 inches in the former. The maximum flood discharge is about 300,000 cusecs and the minimum recorded flow 2,818 at Rupar. (Map 53 A 7, 8, 11, 12).

For the construction of the dam, and the tunnel also, power to the extent of about 3,000 h. p. will in any case be required; and this can be obtained from a site 4 miles from Nangal, on the same loop and below the dam site. Here a minimum of about 15,000 e. h. p. can be obtained under a comparatively low head of about 30 feet, unaffected by the flood rise. The cost, including transmission to the works, is estimated to be about 10 lakhs for the power actually required, but it would seem preferable to so arrange that the whole power can be developed. If the demand later on justifies it, and the tunnel has been built (which would certainly be an advantage in constructing the dam) then the larger project could subsequently be matured. Certainly several thousand h. p. could at once be used for the Kalka-Simla Railway and other [illegible]

Sutlej River—At Khatolu gorge, 2½ miles from Sarahan on the Hindustan-Tibet road, there are cataracts for ¾ of a mile with a single drop of 30 feet included. During the monsoon however the rise of the river practically obscures the falls, so it would only be possible to utilize it with a considerable dam for giving a head. The minimum perennial discharge will be of the order of 1,500 to 2,000 cusecs and the site appears promising, though remote. (Map 53 E, 14, 15).

Canal Falls, Punjab.

Note.—Discharges given are mostly the *normal full discharges*. Minima are being collected and will be available later Serial numbers refer to a map on record in the Survey. Falls less than 8 feet not given.

UPPER JHELUM CANAL.

Serial	Name of channel	R. D	Particulars	Head feet.	Normal full discharge	Minimum discharge
1	Main Line	240,000	Fall	50	8,000 See note.	..
2	Do	418,000	Fall (combined)	20	..	1,000 See Note
3	Gujrat Branch	600	Fall	8	2,083	...
4	Do.	1,350	Do.	8	1,866	.
5	Do	2,000	Do.	8	1,850	...

LOWER JHELUM CANAL.

Serial	Name of channel	R. D	Particulars	Head feet.	Normal full discharge	Minimum discharge
1	Northern Bank	342,080	Fall	8	204	...
2	Do	343,080	Fall } can be combined	8	204	...
3	Do	343,580	Do } can be combined	100	204	...
4	Do.	344,080	Fall	5	204	...
5	Sulki Branch	13,526	Do.	6	357	...
6	Do	14,000	Do	5 5	341	...

UPPER CHENAB CANAL.

Serial	Name of channel	R. D	Particulars	Head feet.	Normal full discharge	Minimum discharge
1	Main Line, lower	715,000	Fall and bridge	8 5	9,070	...
2	Do	221,000	Do	10 5	7,889	..

LOWER CHENAB CANAL.

Serial	Name of channel	R. D	Particulars	Head feet.	Normal full discharge	Minimum discharge
1	Bhawana Branch	7,500	Fall	9 2	423	...
2	Khewra Major Dy	8,000	Do	8 7	314	..
3	Burala Branch	164,000	Do.	8·2	350	...
4	Upper Gugera Branch.	219,000	Do	8 5	...	850 See Note at end.

UPPER BARI DOAB CANAL.

Serial	Name of channel	R. D	Particulars	Head feet.	Normal full discharge	Minimum discharge
1	Salampur feeder	6,486	Rapids No 8 and bridge	8 3	1,895	See Note at end.
2	Do.	33,845	Rapids No. 11 and bridge	9·3	1,824	
3	Main Line	13,300	Rapids No 2	8·0	4,796	
4	Do.	22,500	Rapids No. 6	8 5	4,782	
5	Do.	24,500	Rapids No. 7 and bridge	8 0	4,779	
6	Do.	28,500	Rapids No. 9	8 5	4,773	
7	Do.	31,500	Rapids No. 11	8 5	4,769	
8	Faridnagar feeder.	21,829	Rapids No. 8	9·2	1,774	
9	Do.	27,697	Rapids No 10 and bridge	8 6	1,764	

UPPER BARI DOAB CANAL—*contd.*

Serial	Name of channel	R D	Particulars	Head feet.	Normal full discharge.	Minimum discharge
10	Main Line	54,500	Rapids No 16 and bridge	8·5	4,695	
11	Do.	60,000	Rapids No 18	8·5	4,695	
12	Do.	92,142	Tughal rapid and bridge	8·0	6,292	
13	Do	101,072	Dhambai bridge and fall	8·5	6,300	
14	Do.	114,100	Nanunangal bridge and fall	10·0	6,330	
15	Main Branch, upper.	42,849	Dhariwal bridge and fall	11·0	4,270	
16	Do.	40,768	Kunjar bridge and fall	9·0	4,200	
17	Do	128,500	Aliwal regr and fall	8·0	2,631	
18	Lahore Branch	25,000	Sanchur bridge and fall	10·0	1,080	
19	Do.	96,000	Raneywal bridge and fall	8·6	872	
20	Subraon Branch	34,860	Tughel Walad bridge and fall	8·4	790	

LOWER BARI DOAB CANAL.

Serial	Name of channel	R D	Particulars	Head feet.	Normal full discharge.	Minimum discharge
1	Main Line	329,058	Fall and bridge	8	4,291	See Note at end.
2	Do	493,759	Do.	8	3,774	

SIRHIND CANAL.

Serial	Name of channel	R D	Particulars	Head feet.	Normal full discharge.	Minimum discharge
1	Abohar Branch	23,000	Khanpur	8	2,906	
2	Do.	47,000	Chupki	8	2,888	
3	Do.	69,500	Ballowal	8	2,820	
4	Do.	105,000	Akalgarh	8·1	2,755	
5	Do	128,000	...	8·2	2,657	
6	Do.	213,000	Doodhar	10·0	2,396	
7	Do	254,000	Gholia	8·2	1,957	
8	Do	289,000	Channowal	8·0	1,717	
9	Do	332,000	Samalsar	8·0	1,562	
10	Sultej Nai.	98,000	Baraghar	9·9	400	
11	Do	110,500	Malha	10·0	400	
12	Bhatunda Branch	32,250	Khatra	8	2,029	
13	Do	58,900	Jaghera	7·6	2,011	
14	Do	87,500	Kanganwala	10·1	1,982	
15	Do.	128,000	Lohgarh	8	1,770	
16	Do	185,000	Chambhai	10	1,561	
17	Do.	277,000	Ballohi	8·6	1,039	
18	Do.	307,000	Sadhana	7·7	1,010	
19	Kotla Branch	15,000	Dalowal	9·4	1,427	
20	Do.	56,650	Solar	8	1,414	
21	Do.	61,566	Banbhora	8	1,400	
22	Do.	122,175	Sogra	8·1	1,006	
23	Do.	185,000	Harigarh	8	847	
24	Do.	215,000	Sahoki	8·9	604	

SIRHIND CANAL—*contd.*

Serial.	Name of channel.	R. D.	Particulars.	Head feet	Normal full discharge	Minimum discharge.
25	Kotta Branch	269,000	Ralla	8·5	517	
26	Ghaggar Branch	23,000	Thus	11·1	719	
27	Do.	55,000	Nidampur	8 5	676	
28	Do	135,000	Sular	8·0	311	

WESTERN JUMNA CANAL.

1	Sirsa Branch	168,000	Fatehpur	8·8	1,241	

Of the above it has been suggested by the Chief Engineer that the 50 foot fall on the Upper Jhelum Canal, serial 1, at R. D. 240,000, could be employed usefully at Khewra Salt Mines and Dandot Collieries, but the closure would be a drawback. This may, however, be reduced when the Woolar Lake Barrage in Kashmir has been built. Sir Louis Dane also suggested the employment of this power for irrigation pumping to the tract between the North Western Railway and the Upper Jhelum Canal, where the closure would not matter, but the question of the sufficiency of the supply for the rabi crop would have to be considered. The power available on normal discharge is nearly 14,000 e. h. p. but the minimum and period of closure have not come to hand.

The 20 foot fall on the same canal (serial 2) at R. D. 418,000 could be used at Gujrat and Wazirabad, where some industries exist. The power available on minimum discharge (subject to short closures) is 1,800 e. h. p.

The falls on the upper reaches of the Upper Bari Doab Canal have been dealt with above in connection with the Ravi River. Serial 4 on the Lower Chenab Canal was at one time proposed to be utilized for the "Buchiana Lift Project" of irrigation; it is found however, that the area can probably be commanded by gravitation flow.

There are the following areas of high land within reach of the power and water of the Lower Bari Doab Canal, which could be used for irrigation pumping, *viz.*, Renala, 50,000 acres; Okara, 1,300 acres; Montgomery, 1,750 acres. The closure would not matter for this.

Apart from the power ascertained in these notes on canal falls, those not specially mentioned would yield the following amounts on the discharges given, which are mostly *normal and not minimum discharges*, viz. :—

Upper Jhelum Canal		4,000 e. h. p.
Lower " "		3,300 "
Upper Chenab "		14,500 "
Lower " "		800 "
Upper Bari Doab "	(58,000 total) say	46,000 "
Lower " "		5,800 "
Sirhind "		32,800 "
Western Jumna "		1,000 "
	TOTAL	108,200 "

The power in any particular instance may here be found by e. h. p. $= \frac{\text{cusecs} \times \text{fall in feet}}{12}$

APPENDIX XIV.

Sites in the United Provinces.

Alaknanda.—(See also Bhagirathi River).—This river, also called Vishnuganga, has a catchment area of some 4,500 square miles and 5,000 feet in 16 miles between Badrinath and Vishnuprayag. The gorg miles above Rudraprayag would be difficult to develop and is very out o way; but the river is snow fed and could undoubtedly be developed at a It is reported that the limestone cliffs of the gorge are 150 feet above the of the river at this place, where it takes a sharp bend. An old channel a chord across this bend, with the pilgrim route to Badrinath parallel The suggestion has been made that the old bed could be cut down to the pr water level and sluice gates constructed on it; the river could then be dive while a dam is built across the gorge. Presumably a second dam of the s height would be necessary across the cutting. Arrangements would required for passing timber over. A light railway to Karanprayag is u consideration. (Map 53 J 15-16 or N 3).

Bakher Nadi.—Tributary of Belan, Mirzapur.—There is a reservoir here designed to hold 1,400 million cubic feet of water for irrigation purpo but as the catchment area is 318 square miles with a good run-off and a rai of about 10 inches it is believed that 8,000 million cubic feet or more could reckoned on with a higher dam. Some 87 per cent. of the rain falls betw June and September. The Sirsi fall near by has a drop of 90 feet. project makes an admirable combined irrigation and power scheme, as the waters could be stored lower down and yet above the canal. The site app likely to yield at least 2,000 e.h.p. continuously, and probably much m It is worth further investigation. (Map 63 L 9).

Baur River.—Naini Tal District.—The minimum recorded discharge Dechauri is 9 cusecs and the stream is small and unpromising. (Map 53 O

Belan Nadi.—Mirzapur.—There is a possible reservoir site (unsurvey believed capable of storing 5,000 million cubic feet, above the Mukha fall of to 100 feet, 6 miles west of Ghorawal. It has so far not been examined as cost of the submerged villages and land would be high, but it offers consic able possibilities for power (1,500 e h p. or more) and irrigation combin The catchment area is about 250 square miles with a rainfall of about inches, which practically all falls between June and September. (Map L 9, 10).

Bhagirathi River.—Tributary of Ganges.—At the junction with Alaknanda, at Devaprayag, there are rapids with a perennial snow-fed dischar Reconnaissance is desirable, as the catchment is nearly 4,000 square mil The President of the Council of Regency, Tehri-Garwhal State, has exami this river and its tributaries beyond Barahat, and calls particular attention the Assi, which joins the main river 2 miles above that place. This is a per nial stream, largely snow fed, and has a fall of some 1,275 feet in 8 miles in lower reaches, which are at an altitude of 6,000—7,000 feet. The estima discharge between the 14th and 20th May 1919, was 400 cusecs. The site is miles from Dehra Dun. (Map 53 J, 5, 6, 12).

Chandrapabha River.—Benares State.—There is a small storage site hold some 300 million cub. feet which was surveyed but not proceeded wi A 200 foot fall is said to exist near Baraur. Site not identified, but proba north of the Son River. The power possibilities appear small, though combination with irrigation it might be developed. A request to examine t site has been received through Government. The rainfall is about 40 inches which about 31 inches fall between June and September. (Map 63 P)

Dabka River.—Naini Tal District.—The minimum recorded discharge 10 cusecs at Kota, and the river only offers small prospects of pow apparently. No information as to falls. (Map 53 O 3).

Ganges River.—(See also Bhagirathi River).—It has been recommend that levels should be taken from Rikhishesh up to Phul Chatti or beyon the latter region is believed to offer possibilities, but the harnessing of such river is likely to be very expensive. The site has not been [illegible]

potential power in the river, and it is within the borders of British India, though mostly unsurveyed.

Garai River.—Mirzapur.—For irrigation reasons this is said to be not worth consideration, though a fall of 180 feet exists near the present dam

Gaula River.—Naini Tal District.—The minimum recorded discharge at Kathgodam is 82 cusecs while there are generally at least 100 cusecs through the dry season. The hills fall rapidly from the Bhim Tal District. It is worth further prospecting. Discharges are being taken. (Map 53 O 11).

Gauna Lake.—Garwhal.—This was formed by the great landslip of 1893 and burst in 1894, but the lake is still very large (3 times the size of Naini Tal Lake) and it might be possible to raise a dam there. The Birchi Ganga flows thence to the Alaknanda (Site not identified).

Ghagar Nadi.—Mirzapur.—The water is all required for irrigation, so the power cannot be utilized unless falls exist above the headworks, as to which there is no information at present.

Jagei Lake.—Garhwal.—Formed similarly to the Gauna Lake (q.v.) and the same remarks apply. Snow fed. The Biera Ganga flows from it to the Kaliganga. (Site not identified).

Jumna River.—The scheme of the United Provinces Power Association (Major-General Beresford Lovett) mentioned in Table 5, was a double one. The sites are at Jalanta and Binahar respectively. At the former site a double loop was to be utilized by making two short tunnels through the spur, a canal joining up the tunnels, and giving a fall from R. L. 2,362 to 2,194 or say 168 feet gross. The latter is a single loop, involving a 2 mile tunnel, giving a fall from R. L. 1,953 to 1,698 or 255 feet. The existing concession is partly in Tehri State. Minimum discharge about 750 cusecs; snow fed from a very large area. The promotors of this scheme reckoned, after full investigation, that they could obtain 26,000 e. h. p. at Binahar and 12,000 e. h. p at Jalanta at about one-third of the cost of the larger scheme. It is a matter for regret that for various reasons these promising schemes had to be postponed; it is to be hoped that they are not abandoned. (Map 53 F 14).

Kalaunia Nadi.—This is reported as unlikely to be of any use. It is to the west of the Sarda.

Kaliganga River, Garhwal.—(See also Jagei Lake).—It has been suggested that a large reservoir could be made near Launsari. The stream joins the Kail and the Pindar. (Site not identified).

Kanhar River, tributary of Sone, right bank conditions similar to Rer River (q. v.) and worth investigating. (Map 63 P. 3, 7, 8).

Karanauti, Khajuri, Dahwa and Jargo Nadis, Mirzapur District.—These small nalas rise in the lower scarp of the Vindyas and flow north to the Ganges. There are small storage sites and falls of from 50 feet upwards, but in view of the better sites in the district they are at present not worth more than record. Some power however can doubtless be developed, and might be useful to the neighbouring quarries. Rainfall about 40 inches, nearly all between June and September. (Map 63 K 12).

Karamnasa River, Benares State.—At Nangarh, 40 miles south of Benares, there is a reservoir site investigated by the Irrigation Department and found capable of storing 3,500 million cubic feet at a cost of 12 lakhs; as an irrigation project it was abandoned. A smaller site holding 700 million cubic feet was also located on the Gurwat tributary, 4 miles below Nangarh. Near here there is said to be a fall of 240 feet and another of 100 feet, on the way down to Chakia, where the reservoir of the Benares State Canal is situated; possibly they can be combined. The value to the State of the tail waters of the proposed large reservoir, in keeping the existing irrigation reservoir always supplied, is obvious. The site seems likely to afford at least 4,000 e. h. p. continuously within 40 miles of Benares, probably far more, and is well worth further examination. Details of the sites are available in the Chief Engineer's office. A request to examine the site has been received through Government on behalf of the Benares Darbar, and enquiries have been made by Messrs. Martin & Co. The rainfall is about 40 inches of which 31 inches fall between June and September. (Map 63 P. 5).

Ken River, tributary of Jumna.—At Paind village, Panna State, below junction with Sunai (Sonar ?) there is a favourable reservoir site with a catch-

ment area of 5,700 square miles and a recorded flood discharge of 325,000 cusecs. The site has not been identified. (Map 54 P).

Khoh River, Garhwal.—This falls very low but does not dry up. About 4 miles above Dogadda (on the cart road to Lansdowne) a promontory almost closes the ravine. It was proposed some years ago to make a dam here to generate power for a ropeway between Lansdowne and Dogadda, but the project was dropped in 1914. Site not identified. (Map 53 K 9, 10 ?).

Kosi River, Naini Tal District.—The minimum recorded discharge at Ramnagar is 152 cusecs, and the dry weather flow is generally over 200 here; there are no gaugings higher up, where falls can certainly be developed. The river is not fed from the perpetual snows, but rises in high altitudes in the Almora district, with a rainfall of 50 to 100 inches. November and December only have averages below an inch, though July to September gets most of the rain. The river merits further investigation and is being gauged. Near Hawalbagh it is reported that damming would be feasible and power obtainable. (Map 53,O).

Mussoorie.—In addition to the existing development for Mussoorie and Dehra the Kamptee Falls on the Ringel Gad were mentioned and are to be examined. The catchment is only about 4 square miles. The discharge in 1919 fell to 4·8 cusecs as there was considerable irrigation higher up. A fall of 896 feet can be obtained with a flume of 1,850 feet, and a regulating tank can be built. The minimum discharge of the Bhatta, which supplies Mussoorie (see Table 2) was 8 cusecs in 1919. The Rispana stream had a minimum discharge of 3·8 cusecs in 1919 and a fall down to Mukrat of 720 feet with a pipe line of 4,100 feet. The Aghlar stream is more considerable; it lies between Mussoorie and the range to the north. The discharge below Tonata at the junction of the Khakrana was 54 cusecs; at the Bhilaru junction 41 cusecs; between Kempti and Bhilaru streams 68 cusecs; and at Kempti junction 11 cusecs. The average fall is 150 feet per mile for 6 miles. The country is difficult and transport of machinery would be costly, but this river seems the best for the Mussoorie-Dehra extensions. (Map 53 J 3 ?).

Naini Tal Lake.—The old proposal to utilize this lake for the supply of the hill station is again under consideration of Government. A head of 1,000 to 1,350 feet can be obtained. It is proposed to instal 600 kilowatts (450 working and one spare set) at a cost of 1 lakhs. The storage area, if a dam is built, will be considerable; but the mud flats when the water is low may prove objectionable. (Map 53 O 7).

Nandhaur River, Naini Tal District.—The minimum recorded discharge is 18 cusecs at Chorgallia canal headworks, while the average is considerably higher throughout the dry months, from 22 to 60 cusecs. Falls have not been located and the catchment is small. Rainfall 50 to 100 inches, well distributed. (Map 53 O 12, 16).

Nayar River, tributary of Ganges.—There is a waterfall in the Eastern branch of this river near the Baijran-Kainur Road, 40 miles north-east of Lansdowne (Garhwal). No details are known, but the rainfall in the large upper catchment is about 75 inches. A plan exists, fully worked out, for making an irrigation channel to take out of the Eastern Nayar, a little above its junction with the Western Nayar, to run by a siphon under the latter and then proceed along the Main Nayar to Banghat and Bilkhet. It is said to be possible to adopt a similar project for power purposes at Bilkhet where there is a broad piece of flat land and terraces with a fall of 50 feet. (Map 53 J 16; K 9, 13; N 4).

Paisuni River.—Near Markundi station there is a fall of 150 feet. The river dries up entirely, but the catchment is 175 square miles with a rainfall of 40 inches between June and September. Storage sites may be found. (Map 63 C 16; D 9, 13).

Pindar River.—This snow fed river carries a large volume of water from a very large catchment, and is said to be worth prospecting. It runs into the Alaknanda. (Map 53 N).

Ramgunga River.—This rises in the Garhwal district. At Tarag Tal, in the west Almora Forest Division, a landslip in former times blocked the valley of a tributary and formed a lake; the embankment however is far from water-

The site is worth reconnaissance, but is remote. Catchment area of tributary not known. Rainfall 50 to 75 inches. This is probably either the Gauna Lake (q. v.) or the Jagei Lake (q. v.) but the accounts received do not make it clear. (Map 53 O 1, 2, 5, 6.)

Rer River.—Tributary of Sone, right bank. (Rihand River in Atlas?).—A perennial stream, once estimated as carrying 200 cusecs in May, and therefore probably having a considerable hot weather discharge. Runs in gorges with alternate pools and rapids, but little known. Almost certainly has power, and requires prospecting. Rainfall 40 to 50 inches of which 93 per cent. falls between June and October. (Map 63 L. 15, 16 and P. 3, 4).

Sarasvatiganga River, Garhwal.—Two miles north of Badrinath this river drops 300 feet where it passes through a narrow cleft, spanned by a boulder over which the Tibetan trade route passes. The river is snow fed and has a large hot weather discharge, but as the altitude is 11,000 feet it is unlikely to be of any use. (Map 53 N 5.)

Sardah and Sarju Rivers. Naini Tal District. Details of gaugings are available in the Chief Engineer's office, the river having been completely surveyed for further canal projects. The river is snow fed and the water is used for the Rohilkhand Canals; but falls can almost certainly be developed above the head works, though they may prove to be out of British India, in the kingdom of Nepal, of which the river appears to be the boundary. The upper reaches of the Sardah are called the Sarju, and it is believed that power could be obtained near Bageswar and Rameswar, for the projected ropeways in the Almora District. On the right bank, which is in British territory, the Ledhia, Sarju, Gori, Dharma and Kuti flow in. Of these the Sarju is partly snow fed and has many rapids, and its feeder streams may possibly prove of value also for forestry. The Gori is also snow fed, and should be an excellent source of power, but it is very remote. The Dharma and Kuti also rise in glaciers but are even more out of the way. (Map 62 C 2, 3, 4, 7, 8.)

Tons River.—Lonipur in Rewah State is mentioned, the river having a catchment area of 3,400 square miles in Baghelkhand and a flood discharge of 400,000 cusecs. Site not identified. Higher up, at Poorwa, there is a fall of 100 feet, but here the catchment is reduced to 2,010 square miles. Further up still, at Chachai, 3 miles from Poorwa, there is stated to be a fall of 300 feet; but the dry weather discharge is small and a reservoir site has not been located. The rainfall is about 44 inches of which 41 inches fall between June and September (Map 63 D or H.)

Tons River. Dehra Dun. A site is mentioned near Kalsi, where this joins the Jumna (Map 53 F. 10 or 14).

Note (i)—A full report on the general features of Garhwal and its many streams has been received from the Commissioner, Kumaon Division. The more promising have been entered above, but the list will be useful to the officer examining the district

Note (ii).—There is doubtless great power in the Nepalese rivers Karnali (or Kauriala), Sarju, Rapti, Madi, Budyar, Trisulganga and its tributaries, San Kosi and its tributaries. No data are however available regarding any of these rivers

Canal Falls, United Provinces.

UPPER GANGES CANAL.

Anupshahr branch—

Anikas falls.—Minimum 150 cusecs for 155 days. Fall 5 feet.

Bhagwantpur falls.—Minimum 150 cusecs for 155 days. Fall 5 feet.

Makri falls.—Minimum 220 cusecs for 160 days. Fall 8½ feet.

Jakhera falls.—Minimum 230 cusecs for 160 days. Fall 4 feet.

Dehai falls.—Minimum 250 cusecs for 160 days. Fall 12 feet.

Parichatgarh falls and regulator.—Minimum 325 cusecs for 170 days. Fall 8½ feet.

Dhakauli falls.—Minimum 300 cusecs, but 400 cusecs for 180 days. Fall 7½ feet.

Akbarpur falls.—Minimum 300 cusecs, but 400 for 180 days. Fall 8:8 feet.

Churiali falls.—Minimum 300 cusecs, but 500 for 190 days. Fall 7 feet.

NOTE—The normal flow during most of the year is much greater

Aligarh Division.

Machua falls.—Minimum 600 cusecs for 8 months. Fall $6\frac{1}{4}$ feet.

Somera falls.—Minimum 600 cusecs, but 800 for 8 months. Fall 8 feet.

Palra falls.—Minimum 600 cusecs, but 1,100 for 8 months. Fall 8 feet.

Bulandshahr Division.

Walipura falls.—Minimum 600 cusecs, but 1,300 for 9 months. Fall 5 feet.

Sananta falls.—Minimum 600 cusecs, but 1,500 for 9 months. Fall 1_1 feet.

Dehra falls.—Minimum 600 cusecs, but 1,700 for 9 months. Fall 7 feet.

Dasua falls.—Minimum 600 cusecs, but 2,500 for 9 months. Fall 8 to 9 feet, increasing with low supply. Will give nearly 2,000 e. h. p. for 9 months.

Meerut Division.

Bhola falls.—Minimum 600 cusecs, but 2,700 for 9 months. Fall 12 feet. Will give nearly 3,000 e. h. p. for 9 months. It is anticipated that this fall will be utilized in the near future for the supply of Meerut, but only 750 kilowatts (giving 500 kW with a spare set) are to be installed at a cost of about Rs. 5,00,000. The project is now under consideration of the Local Government. The inlet channel will carry 600 cusecs. 8 miles from Meerut.

Salawa falls.—Minimum 600 cusecs, but 2,900 for 9 months. Fall 12 feet. Will give 3,000 e. h. p. for 9 months.

Chilaura falls.—Minimum 600 cusecs, but 3,000 for 9 months. Fall 10 feet. Will give some 2,700 e. h. p. for 9 months. Near Muzaffernagar.

Jauli falls.—Minimum 600 cusecs, but 3,500 for 9 months Fall 10 feet. Will give about 3,200 e. h. p. for 9 months. Near Muzaffernagar.

Northern Division.

Nirgajni falls.—Minimum 600 cusecs, but 3,600 for 9 months. Fall 12 feet. Will give about 4,000 e. h. p. for 9 months. Near Muzaffernagar.

Mohammedpur falls.—Minimum 600 cusecs but 3,750 for 9 months. Fall 12·2 feet. Will give over 4,000 e. h. p. for 9 months.

Asafnagar falls.—Minimum 600 cusecs, but 3,800 for 9 months. Fall 10·7 feet. Will give 3,700 e. h. p. for 9 months. Near Roorkhee.

Pathri falls.—Minimum 600 cusecs, but 4,500 for 10 months. Fall 10 feet. Will give 4,100 e. h. p. for 10 months. Midway between Roorkhee and Hardwar.

Salempur and Bahadurabad falls.—Already combined and utilized in part. Minimum 600 cusecs, but 4,500 for 10 months. Combined fall 17 feet. Can be developed for nearly 7,000 e. h. p. for 10 months.

Ranipur falls.—Minimum 600 cusecs, but 4,500 for 10 months. Fall [illegible] over 3,600 e. h. p. for 10 months.

Eastern Jumna Canal Upper Division.*

Belka bridge fall.—Minimum 350 cusecs, but 740 for 9 months. Fall $14\frac{1}{2}$ feet.

Dialpur fall.—Same discharge; fall 5·8 feet.

Nogla bridge fall.—Minimum 350 cusecs, but 666 for 9 months. Fall 7 feet.

Babail fall.— Ditto.

Randoul fall.—Same discharge; fall 8·4 feet.

Ghuna and Sarkari falls.—Same discharge; might be combined to give $10\frac{1}{2}$ feet fall.

Hilapur bridge fall.—Minimum 350 cusecs, but 498 for 9 months. Fall $6\frac{1}{2}$ feet.

Megchaper fall.—Same discharge; fall 4·4 feet.

Beri fall.—Same discharge; fall 3 feet.

Malri bridge fall.—Same discharge; fall $4\frac{1}{2}$ feet.

Salampur fall.—Minimum 250 cusecs; fall 5·6 feet.

* All the above have larger discharges as a rule, from 1,000 to 1,770 cusecs.

LOWER GANGES CANAL

Bundelkhand Tract.

Information not yet received.

On the minimum discharges the following power is available (in small units) from these canals; on normal discharge for some 9 months 2 or 3 times the amount could be obtained, *viz.* :—

UPPER GANGES CANAL.

Anupshahr Branch	1,600 e. h. p.
Aligarh Branch	1,200 „
Bulandshahr Branch	1,400 „
Meerut Branch	2,400 „
Northern Division	2,900 „
EASTERN JUMNA CANAL	2,400 „
TOTAL	11,900 e. h. p.

The power in any particular instance may here be found by e. h. p. $= \dfrac{\text{cusecs} \times \text{fall in feet}}{12}$.

Received after going to Press.

Assam.

Cachar.—In the North Cachar Hills, near Subong Tea Estate, it is stated that a valley could be dammed to form a lake in the Abong River. Other similar sites are mentioned near Loobah and Soonamganj; while the Kiang River is said to be worth investigation.

Bengal.

Tista River.—From the Tista Bridge upwards the fall is as follows :—

0 to $2\frac{5}{8}$ miles	15 feet per mile.
$2\frac{5}{8}$ to $12\frac{5}{8}$ „	18 „ „ „
$12\frac{5}{8}$ to $21\frac{3}{8}$ „	32 „ „ „
$21\frac{5}{8}$ to $39\frac{5}{8}$ „	43 „ „ „
$39\frac{5}{8}$ to $47\frac{7}{8}$ „	255 „ „ „
$47\frac{7}{8}$ to $52\frac{1}{8}$ „	228 „ „ „
$52\frac{1}{8}$ to $61\frac{1}{8}$ „	413 „ „ „

Cold weather discharge not less than 1,250 cusecs in North Sikkim.

Bombay.

Bedti R.—Magod falls, near Yellapur (Map 48 J 9). The falls on the branch from the South, 4 miles above the junction, are 328 feet. Falls on the main river 3 miles above the junction are indicated, but not their height.

Ghataprabha R.—At Gokak (q. v.). There are said to be possibilities of extensions, if a new dam is built at Daddi (4″ topo. sheet 242 S. E. 4), and the rapids at Katabali (4″ topo. sheet 274 S. W. 1) are also mentioned.

Kanbargi; 3 miles North of Belgaum. A combined power and irrigation scheme is suggested, a drop of 400 feet being feasible.

Markandaya R.—There is a good waterfall on 4″ topo. sheet 274 N. E. 3.

Nagargali.—There is a perennial stream with a waterfall between Duggeli and Kirpoli, on 4″ topo. sheet 277 N. W. 4.

Sonda Nala.—Near Ibihalli, Sirsi Taluka. The falls are over 300 feet high. (Map 48 J 13; 14).

Burma.

Lilu Ch., tributary of Mon, near Paungseik.—A fall of 100 feet with perennial flow reported. Shwegyin Division.

Maisakhaing Ch. near Kyankpon.—Two falls of 50 and 75 feet reported, with perennial flow. Also, higher up, two falls of 40 and 100 feet known to the Karens as the Donwe and Kyaukoh Falls.

Pada Ch., near Khedo.—A fall of 100 feet reported with perennial flow. Shwegyin Division.

Central Provinces.

[redacted]

Narbada R.—Gaugings were taken at Khiranighat, near Jubbulpore, during March, April and May 1919. The catchment area there is 6,500 sq. miles. The maximum flood discharge recorded up to date is 2,395 cusecs on 20th March 1919. The mean discharges were as follows :—

March 13th to 15th . . .	519 cusecs	Minimum 412 cusecs.
„ 16th to 31st . . .	933 „	
April 1st to 15th . . .	405 „	„ 173 „
„ 16th to 30th . . .	254 „	
May 1st to 15th . . .	239 „	„ 145 „
„ 16th to 26th . . .	215 „	

Total flow in period 2,791 million cubic feet.

The *Kapadhana Falls* below Amarkantak are about 100 feet.

Nimgahan.—At altitude 2,700 feet there is a perennial stream with a drop of 1,000 feet in a short distance.

Penganga R.—Kinwat Forest Reserve, Berar. The Sahasrakund fall near Bittargaon (Map 56 I 3) is 120 feet. A further possible site is indicated on sheet 56 I 5, in the Kolapur Forest Reserve.

Rakshadah Fall.—This is on the border of the Lurmi Range and Mandla District, near Berar Pani. Said to have a drop of 1,300 feet in a mile.

Madras.

Kolab R.—At Bargra near Jeypore; (Map 65 J 9). There is a site for power here, reached by a footpath of about 4 miles from the Jeypore ghat, at mile 58-0 on the road. Three falls exist of some 150 to 180 feet in the aggregate, but by utilizing a reservoir site higher up a fall of 800 feet may be obtainable. A sketch has been forwarded, but gaugings have not so far been reported. It is worth further examination as the tail waters could be used for irrigation on the Jeypore Plateau.

Machkand R.—The Duduma waterfall near latitude 18° 31½′, longitude 82° 31½′ (or 82° 28′ as shown on Atlas sheet 65 J on the ¼″ scale) has been measured and found to be of 540 feet. A float gauging made at the beginning of May, said to be at the driest time showed 104 cusecs with a coefficient of 0·5. The site is reached from Bugura, 22 miles off, by a footpath. A large reservoir site exists just above the falls, and it is probable that there are many others higher up still. No details are given as to capacity, but the site is certainly good for 5,000 e. h. p. or more. Vizagapatam, where the harbour works will require power, is 80 miles distant.